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LOCAL GOVERNMENTS

LANDSAT APPLICATIONS PROGRAM

FINAL REPORT

CONTRACT NAS5 - 24335

EASTERN REGIONAL REMOTE SENSING
APPLICATIONS CENTER

NASA GODDARD SPACE FLIGHT CENTER

PUBLIC TECHNOLOGY, INCORPORATED
1140 CONNECTICUT AVENUE, N.W.
WASHINGTON, D.C. 20036

Acknowledgments

Public Technology, Incorporated would like to thank the many individuals and organizations that have contributed to this program. The effort described herin has been supported by the Eastern Regional Remote Sensing Applications Center (ERRSAC) at the NASA Goddard Space Flight Center, Greenbelt, Maryland.

Initial support for the project concept came from Joseph Carlson and Stanley Goldberg at PTI; Philip Cressy, Head, and Albert (Buzz) Sellman at ERRSAC; and the local government officials who participated in the program. The support and guidance of Scott Cox, who served as project technical monitor, and ERRSAC members James Webber, and William Alford is appreciated.

The local government officials who supported and participated in the program are listed in Table 1.1. Without their interest and dedication this project would not have been possible.

Drs. George McMurtry and Gary Petersen, and the entire staff of the Office for Remote Sensing of Environmental Resources at Pennsylvania State University deserve special thanks for the remote sensing training course provided the project participants and their continued support and assistance with the ORSER system throughout the project.

The author would also like to acknowledge the contributions of Beldon Bly of Computer Science Corporation; Dr. Charles Barb of the University of Oklahoma; and Wayne Moonyhan and Roy Estes at NASA Earth Resources Laboratory.

The project manager at PTI was Ned Buchman. Views and opinions expressed in this report are those of the author, and do not necessarily represent those of the sponsor or local government participants.

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1.0 MANAGEMENT REPORT

1.1 Project Summary

The National Aeronautics and Space Administration (NASA) has established the Regional Remote Sensing Applications Program to develop the institutional environments and technical capabilities within state and local governments for the interpretation and use of satellite remote sensing data in routine operations. Under this program, responsibilities are regionally distributed among three NASA field centers:

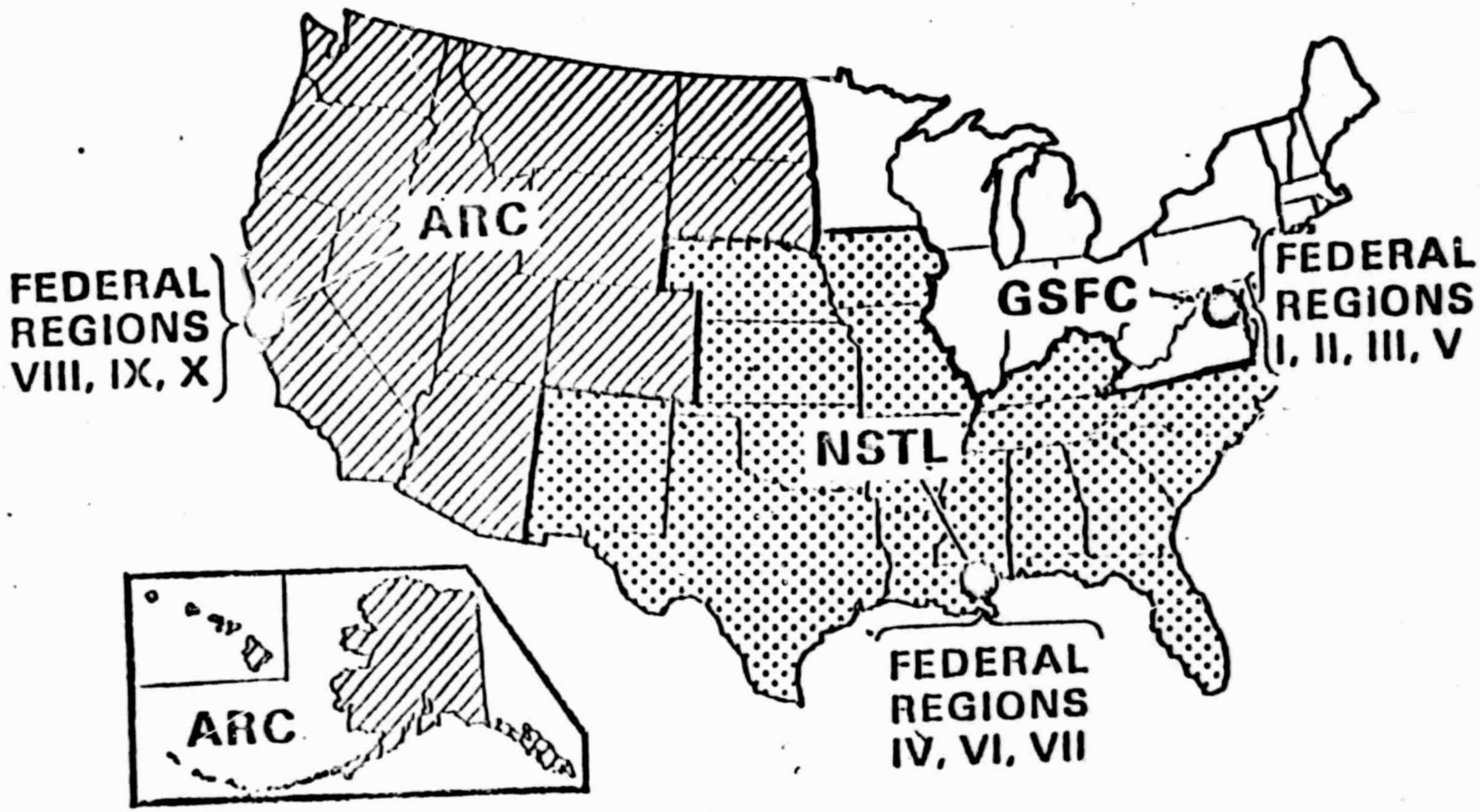
- The Goddard Space Flight Center (GSFC) in Greenbelt, Maryland
- The National Space Technology Laboratories (NSTL) in Bay St. Louis, Mississippi
- The Ames Research Center (ARC) in Sunnyvale, California

The Regional Program is designed to accomplish its goals through the use of orientation programs, training activities, application demonstrations, and technical assistance. Of these approaches, "demonstration projects are the key element of the program, providing state and local governments with the opportunities to become familiar with data processing and analysis techniques in their own operational settings, and to apply this knowledge to their own information needs." 1/

In August, 1977, Public Technology, Inc. (PTI) proposed to the Eastern Regional Remote Sensing Applications Center (ERRSAC) at Goddard Space Flight Center to coordinate and manage a 15 month experimental Local Governments Landsat Applications Program. The purpose of the program was to formulate policy recommendations for transferring remote sensing technologies to local governments.

FIGURE 1.1

REGIONAL REMOTE SENSING APPLICATIONS PROGRAM



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Local planners from five jurisdictions were trained to perform digital image analysis of Landsat multispectral imagery. The cities selected applications based on local needs, priorities, and interests; and conducted application demonstration projects under realistic operational conditions with minimal technical assistance. Project costs were shared by the cities and NASA. The cities commited personnel time and computer terminals, while NASA provided the training, processing time, long distance telephone lines, satellite data and travel.

1.2 Description of Technologies

Remote sensing is the science and art of acquiring information about material objects or phenomena from measurements made at a distance, without coming into physical contact with the objects. The utilization of remote sensed data for purposes of resource planning or management requires several technologies, each involving its own theories, instruments, and techniques. These technologies are combin in a total management information system. These technologies can be grouped into three general areas as follows:

1. Data Collection - sensors, platforms, communications, and data dissemination.
2. Data Analysis - correction, enhancement, pattern recognition, identification, measurement, cartographic presentation.
3. Data Use - data integration, information storage and retrieval, modeling, decision support methods.

The Landsat earth resources satellites developed by NASA are a data collection technology. The ORSER digital developed by the Office for Remote Sensing of Environmental Resources is a data processing system used for data analysis technology. Several data use technologies have been developed by investigators and Landsat users, many of them supported by NASA grants or contracts. Both Landsat and ORSER

Table 1.1 List of Local Government Participants

<u>Atlanta, Georgia</u>

Collier Gladdin, Director, Bureau of Planning

Wistar Harmon, Assistant Zoning Administrator

Steve Grilli, Zoning Assistant

<u>Henrico County, Virginia</u>

Robert J. Dahlstedt, Planning Director, County Planning Office

Cheryl Evans, County Planner

Lawrence O'Keefe, Technology Agent

<u>Minneapolis, Minnesota</u>

Perry Ludvig, City Planner

Norman Yarosh, Technology Agent

<u>Oklahoma City, Oklahoma</u>

Norman Standerfer, Planning Director, City Planning Department

Roy Reynolds, Senior Planner

Gerald Johnson, Planning Assistant

James Carter, Assistant City Manager, Technology Agent

<u>San Jose, California</u>

John Berg, Planner, City Planning Department

Gary Zouzoulas, Office of Science and Technology

Monroe Postman, Technology Agent

have been described in detail elsewhere,[2,3] but are briefly described below. Application technologies used by the local governments involved in the program are described in Section 3 of this report.

1.2.1 Landsat Earth Resources Observation Satellite

The Landsat program to date consists of three experiemental satellites developed by the NASA Earth Resources Technology Satellite (ERTS) program and jointly operated by NASA and the Earth Resources Observation Systems (EROS) Program of the U.S. Geological Survey. Landsat-1 was launched July 23, 1972 and operated until January 6, 1978. Landsat-2 was launched January 22, 1975 and is still operating. Landsats 1 and 2 are identical in terms of the data they produce. Landsat-3, launched March 5, 1978 has the same orbital characteristics as Landsats 1 and 2 but a slightly modified sensor system.

The primary image producing sensor onboard Landsat is the multispectral scanner (MSS). This electronic system collects radiometric data in four spectral bandwidths (or channels) - two in the visible portion of the spectrum at .5 - .6 microns (green) and .6 - .7 microns (red), and two in the reflective near infrared at .7 - .8 microns and .8 - 1.1 microns. The Landsat-3 MSS has an additional channel in the thermal (a) infrared at 10.4 - 12.6 microns. The data are either directly telemetered to U.S. ground data acquisition stations in Alaska, California, and Maryland or to foreign receiving stations, or stored on tape until the satellite comes within receiving range of a ground station. At the NASA Goddard Space Flight Center, the managing center of the Landsat program, the satellite signals are converted into an image format. For each "scene" an image is produced of each of the four spectral bands (Figure 1.2). A Landsat image covers 115 x 115 statute miles. The nominal spatial resolution of the MSS is about 80 meters (260 feet), equivalent to a picture element (pixel) of approximately 1.1 acres.

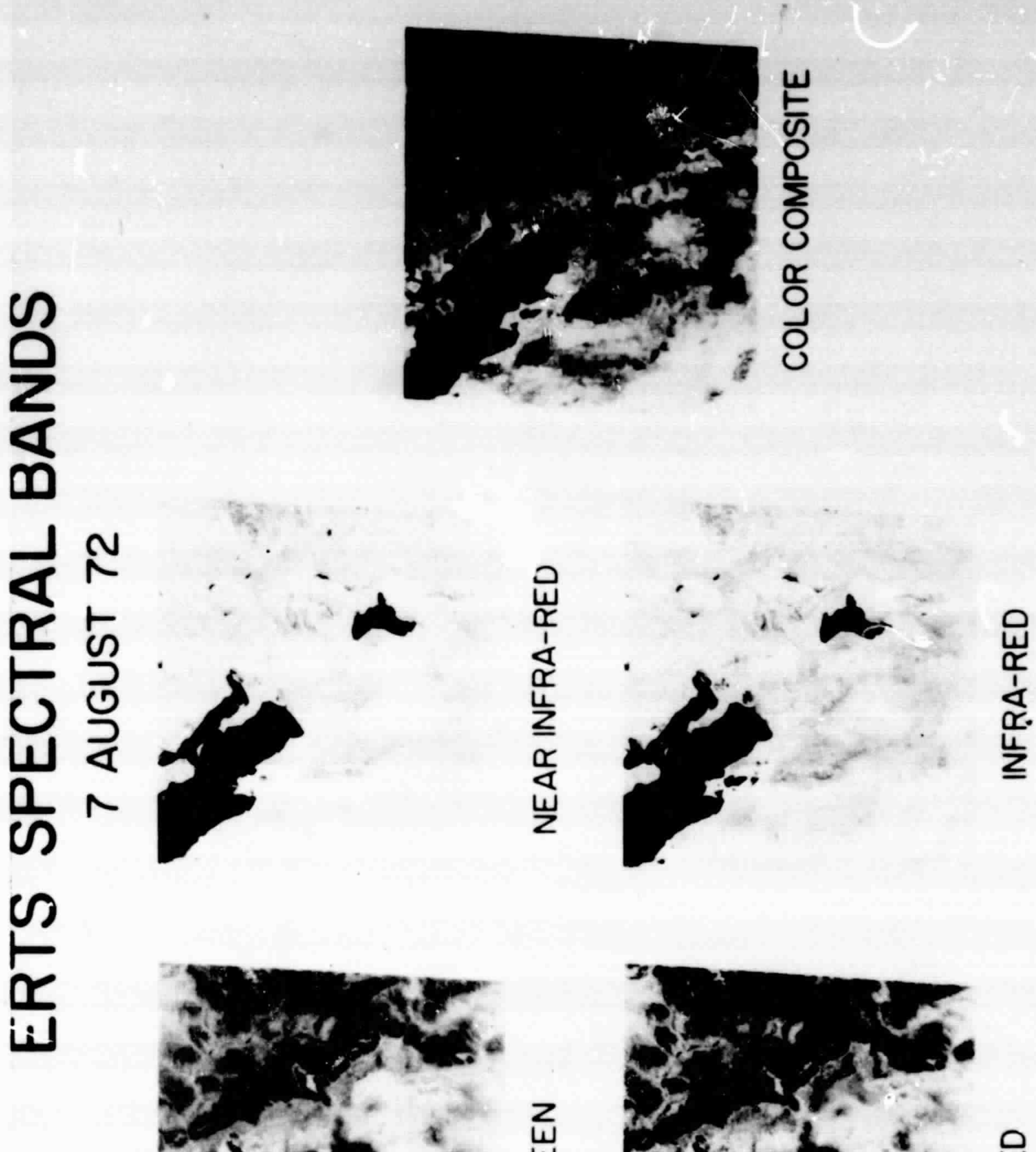

Figure 1.2 Landsat Multispectral Scanner (MSS) Images

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COLOR PHOTOGRAPH

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Images of the individual MSS bands can normally be obtained as either prints or transparancies at scales ranging from 1:3,369,000 (2 X 2 inches) up to 1:250,000 (29.2 x 29.2 inches). Color images called "color composites" are produced by combining three of the MSS bands in registration and sequentially exposing them through appropriate color filters onto color film (Figure 1.2).

By convention the colors are usually selected to give the same appearance as color infrared photography. These are called "false color" because there is no natural blue color. In these false color composites vegetation appears red; water dark blue; and urban areas blue-gray. Resource information can be interpreted from these single band or color composite images manually in much the same way as aerial photographs are interpreted.

The radiometric information from the MSS sensors can also be stored on computer compatible tapes (CCT's). The data on these CCT's can be combined, manipulated, and processed by computer systems to enhance certain image characteristics which are then recorded on film, or to extract thematic information which is reproduced as maps or statistical tabulations.

In late 1981, NASA plans to launch a fourth Landsat satellite incorporating a new 7-channel multispectral sensor system called the Thematic Mapper, together with a 4-channel multispectral scanner (MSS) similar to those on Landsats 1 and 2. The Thematic Mapper will provide higher spatial resolution (0.2 acres) and other improvements expected to result in better identification and classification of agricultural and geologic resources.

1.2.2 ORSER Digital Data Processing System

The Office for Remote Sensing of Earth Resources (ORSER) of the Space Science and Engineering Laboratory (SSEL) at Pennsylvania State University

has developed an extensive computer software system for processing and analyzing Landsat and similar multispectral data. The automatic data processing equipment used in the ORSER system is primarily located at the Pennsylvania State University Computation Center. A Remote Job Entry (RJE) system permits university and non-university users to use an IBM 370/168 computer (now an IBM System 3033) from any compatible remote terminal, including equipment tied in by long-distance telephone lines.

No program card decks are needed to operate the ORSER system. The MSS data processing programs are kept in file libraries on the main computer. MSS data are imput from magnetic tapes which along with "user-owned" working tapes, are managed by the Computation Center. Computer files for building program control information or for storing output are available to the user. The preparation of program control specifications by a user operating from a RJE terminal is accomplished by conversationally editting a stored file containing IBM job control language (JCL) statements. Each ORSER program accepts the input control specifications, processes the MSS data according to these specifications, and outputs the results to the user's RJE terminal. The ORSER programs are queued with the programs of other Computation Center users and are processed in batch mode in order of entry and priority. Typical turn-around time from an RJE terminal is 2 to 10 minutes depending on the size of the program and the number of other users on the system.

The ORSER system was developed for use by a variety of remote sensing researchers. As such, the procedures for using the ORSER programs for specific applications and type of data are established by the individual user. A generalized processing procedure as shown in Figure 1.3 consists of the following steps:

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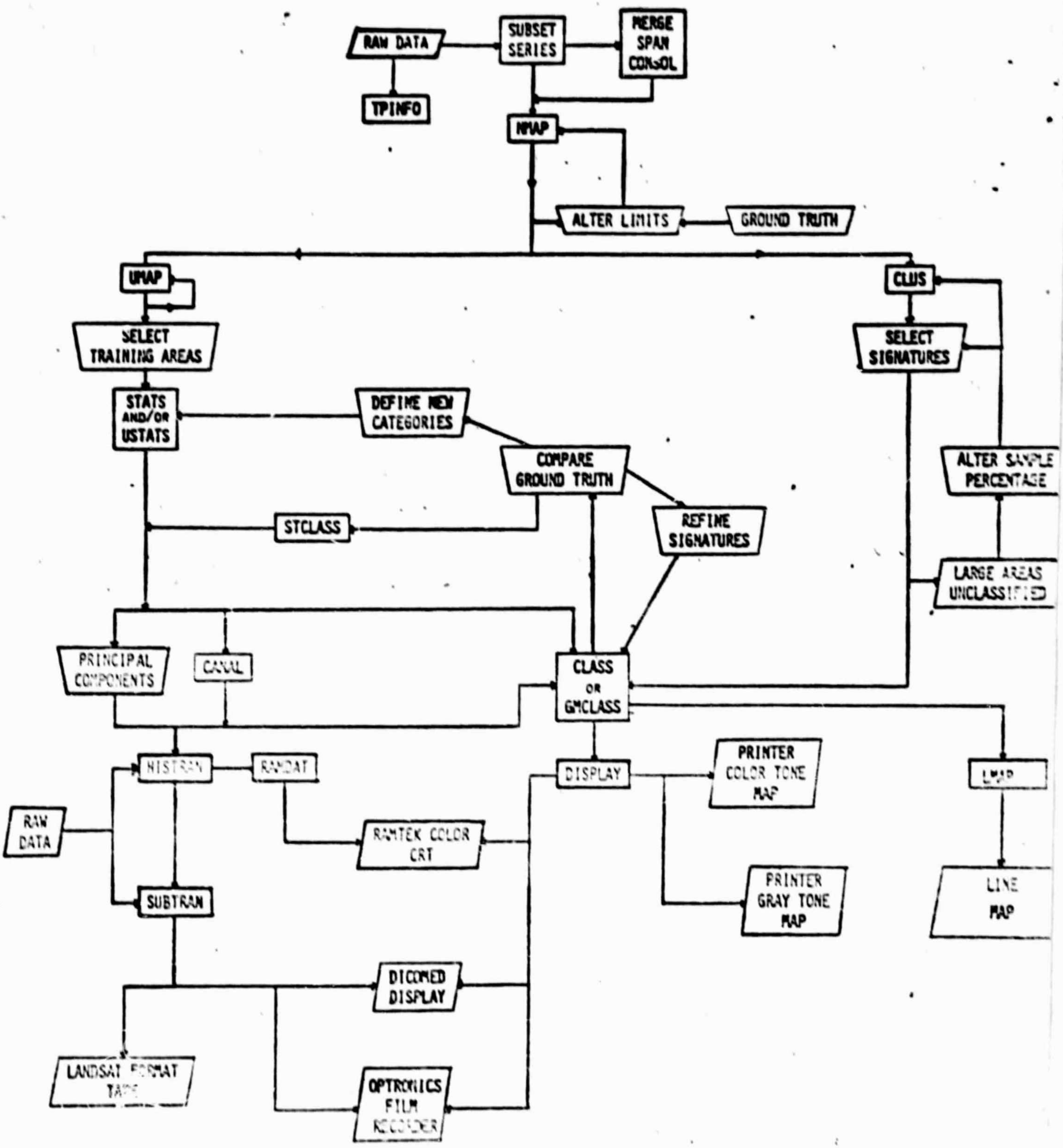

Figure 1.3 Generalized Landsat Processing Flow Using the ORSER Digital Data Processing System

SUBSETTING - an image area of interest is selected and reformatted into a common ORSER program format.

GEOMETRIC CORRECTION - MSS data are resampled, rotated, and scaled to register with a map.

IMAGE ENHANCEMENT - MSS response values are transformed by ratioing channels, averaging channels, linear translation, or principle components of the channels (optional).

STATISTICAL TRAINING - multivariate statistics of MSS values computed for training areas defined from image brightness and local uniformity maps.

CLASSIFICATION - an algorithm is used to assign picture elements into categories based on the MSS response values of the element and the multivariate statistics of the categories.

OUTPUT - classification map is printed in cloor on a line printer or formated for display on a plotter, film recorder, or a color CRT.

The outputs of the ORSER programs consist primarily of statistics, character maps, and summaries which the user can store as computer files or print on a RJE terminal. The programs are couched in a multivariate statistics framework; i.e., each picture element (pixel) is treated as a vector of P variable, where P is the number of MSS channels, and the vector endpoint is determined by the MSS response values (gray levels). Many of the programs compute the Euclidean distance between two vectors; i.e., the distance between the vector endpoints.

The ORSER system of programs are available from the Office for Remote Sensing of Earth Resources at Pennsylvania State University for a charge of $700. As of November, 1977, the complete system had been supplied to fourteen other universities, federal agencies, foreign governments, and private research/consulting firms.

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1.3 Summary of Conclusions

All participating jurisdictions developed sufficient basic internal capabilities to suggest that local planners could be trained to process Landsat data. Institutionalization of self-sufficient remote sensing programs would require an additional 1-2 years to complete. The PSU/ORSER course was effective in training the local planners to process Landsat data, but continuous training mechanisms are required to develop sufficient proficiency. Forms of personal contact were most effective in training local planners. Additional statistical training and/or assistance was needed to provide the planners with stronger understandings of the Landsat processing techniques. Also more extensive documentation which does not assume previous computer or remote sensing experience was needed.

Landsat data produces land cover information which cannot generally be used as a substitute for urban land use information. Lack of proven applications and decisions support models for using land cover information in local land use planning were a major limitation in the participants' ability to utilize the Landsat derived information. Other problems included the resolution and uncorrected geometric errors in the Landsat data.

Landsat appears to be applicable for calibrating urban hydrologic models of stormwater runoff, flooding, and water quality; conducting vacant land inventories and vegetation analyses; and producing regional scale Level I land cover classifications. Landsat may also be applicable for monitoring land use changes at the urban fringe but operational procedures for accomplishing this have not yet been developed.

Local planners can operate digital image information extraction systems. However local governments' capabilities for supporting and maintaining these

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systems is limited. Existing image information extraction systems are designed primarily for remote sensing researchers, and are not attuned to the needs of local planning agencies.

Institutionally, the greatest issue inhibiting the transfer of satellite remote sensing to local governments is the lack of a packaged methodology for applying the Landsat data to solve a major problem facing local officials. Local officials could perceive that Landsat had much potential for helping them solve local planning problems, but the technical process through which the Landsat data would be brought to bear was ambiguous. The lack of a packaged applications methodology was a major factor restricting the local resources committed to the Landsat project by the local governments.

Within local governments, the scattered, uncoordinated nature of mapping and land use information functions, lack of "slack resources," and limited data processing capabilities are major institutional factors which limit the transferability of satellite remote sensing technologies. Development and transfer of geographic-based information systems (GBIS's) capable of integrating remote sensing data with other data sources and local administrative records would increase local governments' abilities to utilize remote sensing data.

The remote sensing transfer process should emphasize well-defined benefits of remote sensing applications; provision of sufficient technical assistance to enable adaptation of the technology to local needs and constraints; inclusion of top-level local decision makers in establishing local project goals, and capacity building of sufficient local personnel to enable self-sustaining program continuation.

1.4 Summary of Recommendations

Major policy recommendations resulting from the Local Governments Landsat Applications Program are:

1. Establishment of a Local Governments Space Technology Applications Program to develop the awareness of local elected officials and key decision-makers of the capabilities and benefits of space technology including remote sensing, and involve them in planning for future space programs.
2. Initiation of an Urban Management Information Systems Program to research, develop, and test urban applications of remote sensing for managing urban land resources.
3. Support for the development and/or transfer of geographic-based information systems enabling local governments to better coordinate, manage, and apply land use information.
4. Development of a Remote Sensing Project Manager's Guide and other user documentation to assist local managers to conduct remote sensing projects and implement operational remote sensing programs.
5. Continue to provide local and state government personnel with remote sensing and information systems training.
6. Package proven remote sensing applications for transfer. Two urban applications of Landsat should be documented: calibration of hydrologic models and change detection.
7. Development and testing of low-cost operational user oriented information extraction systems including utilization of digitally enhanced photographic images, microcomputer based image analysis systems, and integrated information extraction/geographic information systems.

8. Demonstration and assessment of a variety of transfer arrangements for utilizing satellite remote sensing in local governments.
9. Development of a structured process for local and state governments to procure remote sensing services and products from private industry.
10. Utilization of a local project team approach in remote sensing demonstration and transfer project.
11. Provision of technical assistance to local governments in adapting remote sensing technolgoy to local needs and constraints.

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1. Dr. Anthony J. Calio, Associate Administrator for Space & Terrestrial Applications, National Aeronautics and Space Administration, statement on 27 June 1978, in U.S. House of Representatives Hearings, 95th Congress, 2nd Session, before the Subcommittee of Space Sciences and Applications of the Committee on Science and Technology, unpublished prepared materials, p.8.

2. National Aeronautics and Space Administration, Landsat Data Users Handbook, Goddard Space Flight Center, Greenbelt, Maryland, September 2, 1976.

3. Office for Remote Sensing of Earth Resources, ORSER Users Manual, ORSER Technical Report 9-78, Pennsylvania State University, University Park, Pennsylvania, 1978.

2.0 PROJECT DESCRIPTION

2.1 Background

In 1974, PTI surveyed the technology agents in the 27 jurisdictions participating in the Urban Technology System (UTS) on potential applications of remote sensing technology (Table 2.1). Twenty-four applications were identified in seven general areas: land use, land use change, water resources, water quality, environmental assessment, air quality, and updating population information. Subsequently, under contract to the Information Transfer Laboratory (Intralab) at NASA's Goddard Space Flight Center, PTI formed a Remote Sensing Applications Requirements Committee to study the feasibility of utilizing NASA developed satellite remote sensing and digital image processing technologies for these needs. The Committee consisted of technology agents and management personnel from five jurisdictions: Atlanta, Georgia; Henrico County, Virginia; Independence, Missouri; Minneapolis, Minnesota; and San Jose, California.

A six month pilot study was conducted using San Jose as the lead site. A local planner was trained to interpret Landsat data with the ORSER system via a remote computer terminal which was installed in the city planning department. The results of the pilot study showed that this approach was technically feasible and the Committee recommended the program be expanded to all five sites so they could evaluate the applicability of the Landsat data and digital image processing techniques to local problems.[1]

TABLE 2.1

URBAN REMOTE SENSING APPLICATIONS IDENTIFIED
UTS TECHNOLOGY AGENTS, 1974

LAND USE

- Reduce Time and Cost to Prepare Land Use Maps
- Map Generalized Urban Patterns
- Provide Non-Site Specific Land Use Information
- Urban Form Analysis/Urban Blight

LAND USE CHANGE

- Agricultural To Urban Land Conversion
- Monitor Urban Expansion
- Determine Effectiveness of Growth Control Techniques

WATER RESOURCES

- Map Inland Wetlands
- Flood Damage, Channel Changes
- Floodplain Mapping
- Drainage Patterns and Networks
- Ground Water Resources and Usage in Arid Regions

WATER QUALITY

- Early Detection and Tracking of Red Tide
- Identify Point and Non-Point Water Pollution Sources
- River and Lake Water Quality

ENVIRONMENTAL ASSESSMENT

- Environmental Change Due to Development of Large Facilities (Reservoirs, Recreation Areas)
- Environmental Impact of Power Generating Plants
- Existing and Potential Open Space
- Inventory of Trees

AIR QUALITY

- Map Patterns, Densities, and Flow of Point and Vehicular Created Emissions
- Impact of Power Generating Plant Emissions (Fly Ash)

UPDATE POPULATION INFORMATION

- Population Estimates
- Monitor Urban Growth
- Land Use Densities

2.2 Purpose and Objectives

The overall purpose of the Local Government Landsat Applications was to formulate policy recommendations for transferring Landsat technology to local and state governments. Particular emphasis was placed on identifying and understanding the institutional factors within the users' organizations and within the users' environment which will influence the potential transferability of Landsat and its related technologies. Issues to be evaluated included:

1. Can local governments develop an internal capability to understand and utilize Landsat data?
2. For what applications important to local planning is Landsat suited?
3. Can low cost digital image processing systems be used in operational local government remote sensing programs?
4. What are the organizational and institutional issues influencing the transferability of Landsat?
5. What methods can be used effectively to transfer Landsat technology to local governments?

2.3 Approach

In order to develop the internal capabilities of local governments to handle and evaluate Landsat data, it was recognized that the participants would require: (1) training of local personnel; (2) a low-cost digital imaging processing system; and (3) technical assistance.

2.3.1 Remote Sensing Training

Training was provided by the Office for Remote Sensing of Earth Resources (ORSER) at Pennsylvania State University. Each jurisdiction sent one representative to a two-week Remote Sensing Short Course. The first week of

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the course dealt primarily with the principles of remote sensing and the ORSER programs, and the second week with applying the ORSER programs to Landsat scenes of each city. The format of the course involved both lectures and laboratory exercises. During the first week the laboratory exercises used a Landsat scene, aerial photographs, topographic maps, and collateral data of a test site selected by the Office for Remote Sensing; during the second week each participant worked with Landsat imagery selected by NASA-ERRSAC of his or her jurisdiction.

2.3.2 Digital Image Processing System

The ORSER digital data processing system was selected for the Program because it could be easily installed in each of the participants' planning departments; required minimal special equipment to use; software and data files could be maintained at a central facility and would not have to be installed locally; and the ERRSAC staff had previous experience in using the system. The ORSER system operates in remote batch mode on an IBM 370/168 at Pennsylvania State University. Access is through keyboard teleprinter or CRT display terminals connected to the computer via low-speed dial-up telephone lines. System capabilities include data formatting; merging, scaling and rotation; data transformation; training site selection; statistical signature extraction; canonical analysis; thematic classification; and map comparison. Classification can be performed using Euclidean distance, angular separation, parallelepiped, or clustering algorithms. Principle outputs are statistics and line printing character maps, although film recorder, line plotter, and color CRT displays are also possible.

TABLE 2.2

SCHEDULE FOR PSU/ORSER SHORT COURSE
ON
REMOTE SENSING, OCTOBER 31 TO NOVEMBER 11, 1977

Day	Activity	Format
1	Introduction and purpose of course	L
	History of remote sensing	L
	Electromagnetic spectrum, energy/matter interactions, spectral signatures	L
	Landsat MSS sensors and products	L
2	ORSER System computing environment	L
	Linear algebra	L
	ORSER programs SUBSET, TPINFO, RJE	P
3	ORSER programs NMAP, UMAP, STATS, USTATS	L, P
4	Pattern recognition	L
	ORSER program CLASS	L, P
5	Applications: Urban, Agriculture, Forestry, Land Use	L
	ORSER program CLUS	L, P
6	Geometric Correction	L
	ORSER programs GMCLASS, SUBGM	P
	Practicum using city data (open lab)	P
7	Photo sensors, stereoscopy	L, P
	Photoanalysis, photogrammetry	L, P
8	Digital display devices and equipment	L
	Open lab	P
9	Ground truth support, mission planning	L
	Data bases, multistage/multidate sampling	L
	Open lab	P
10	Ordering Landsat data	L
	Processing costs	L
	Open Lab	P

Legend: L = Lecture
P = Practicum

2.3.3 Technical Assistance

Technical assistance was provided by PTI's Project Coordinator and ERRSAC's support contractor Computer Science Corporation (CSC). Principal means of assistance was through regular telephone contacts. Computer terminals at both PTI and ERRSAC were used to analyze problems with ORSER programs. A series of technical notes was established to notify participants about common questions; a total of ten technical notes were prepared during the Program. Finally, participants could request on-site assistance with training, project organization, or problems which could not be resolved via the telephone or remote terminal.

2.3.4 Other Characteristics of Approach

Other key characteristics of the Program methodology included:

- Cost Sharing -- in order to provide for a more realistic market test of Landsat data applications, the local government participants committed staff time and the cost of the computer terminals to the project. NASA contributed the training, computer processing time, telephone charges, and travel.
- Program Management and Coordination -- provided by PTI which has extensive experience in managing user needs assessment and technology applications programs with local governments.
- Networking -- to enable the participants to share their experiences, provide for aggregation of common needs, and allow potential expansion to other cities and counties. The project utilized the existing technology network of the Urban Technology System and PTI subscribers who were kept informed of the progress of the project through network and project meetings and articles in PTI News.

2.4 Schedule and Milestones

The schedule for the Local Governments Landsat Applications Program is shown in Figure 2.1. The eighteen month project was organized in three broad phases each lasting approximately six months. First was the capacity building phase during which local personnel received training, remote computer terminals were installed in each city, demonstration project objectives established, demonstration plans developed, and resources and collateral data obtained and organized. The second phase was the demonstration projects phase during which the Landsat data were analyzed and applied to local planning issues. The last phase was the evaluation and report writing phase during which the cities were surveyed regarding the results they had obtained, the impacts of the project, the problems encountered, and the requirements needed to proceed to a transfer phase.

Major project milestones were:

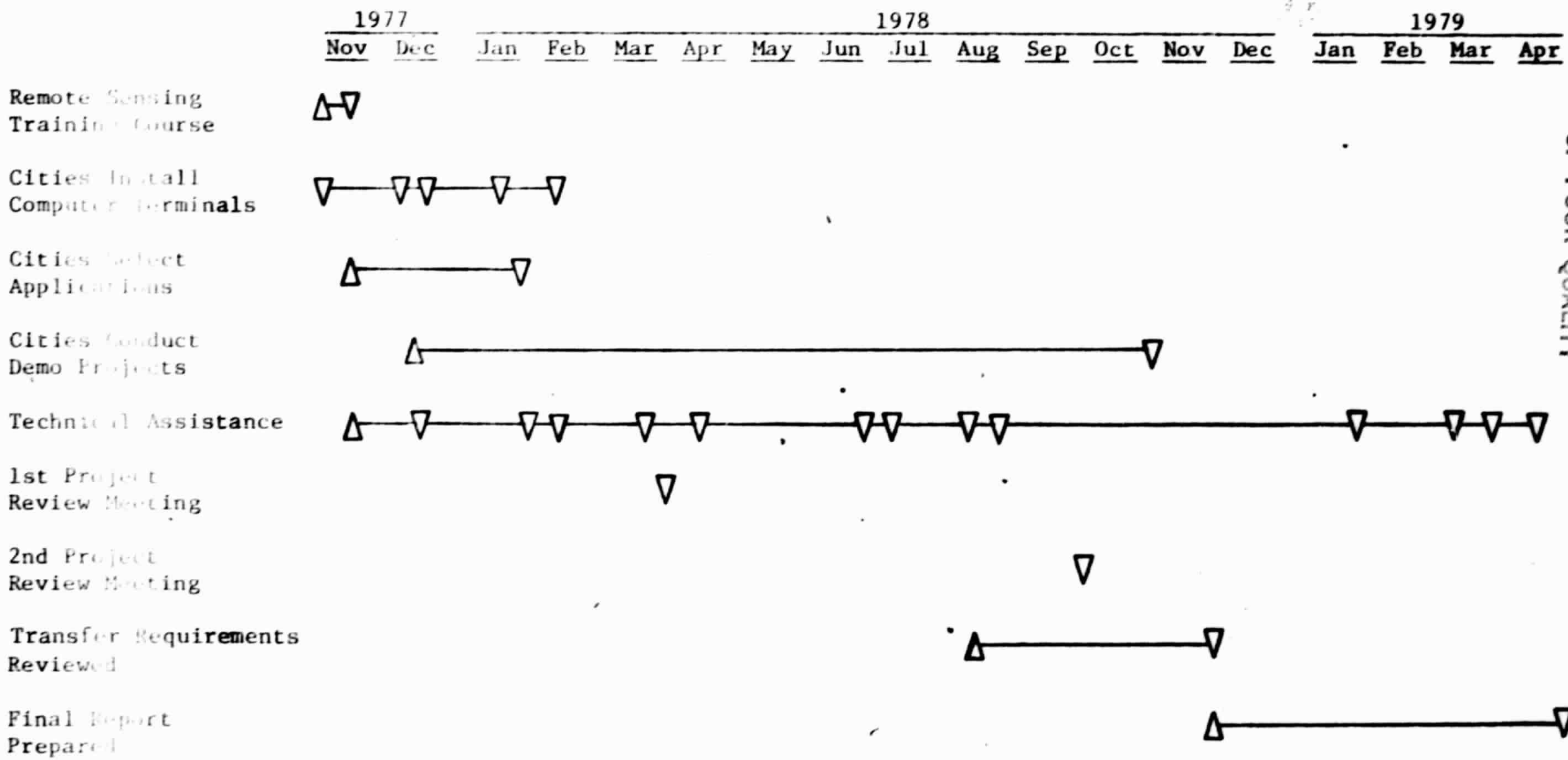
- Remote Sensing Training Course, October 31 to November 11, 1977, given by the Office for Remote Sensing of Environmental Resources (ORSER) at Pennsylvania State University.
- First Project Review Meeting, March 28-30, 1978, at NASA's Goddard Space Flight Center in Greenbelt, Maryland. Capacity building phase essentially completed; application demonstration phase under way.
- April 1978, inputs made to the Intergovernmental Science, Engineering and Technology Advisory Panel (ISETAP) Natural Resource and Environment Task Force study on State and Local Government Perspectives on a Landsat Information System.[2]
- Second Project Review Meeting, September 28-29, 1978, at NASA's Earth Resources Laboratory in Slidell, Louisiana. Demonstration projects completed

or near completion; evaluation and report writing phase begun.

- November 1978, Atlanta, Oklahoma City, and San Jose submit recommendations and requirements to continue program-into-transfer phase to the Eastern Regional Remote Sensing Applications Center.

FIGURE 2.1

LOCAL GOVERNMENTS LANSAT APPLICATIONS PROGRAM
SCHEDULE AND MILESTONES



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1. Public Technolgoy, Inc., Application of Remote Sensing to Urban Land Cover Analysis Through the Urban Technology System Network, Final Report, NASA Contract NAS5-22412, Washington, D. C.

2. Natural Resource and Environment Task Force of the Intergovernmental Science, Engineering, and Technology Advisory Panel, State and Local Government Perspective on a Landsat Information System, Washington, D.C., June, 1978.

3.0 LOCAL GOVERNMENT EXPERIENCE

Five local governments - Atlanta, Georgia, Henrico County, Vrginia, Minneapolis, Minnesota, Oklahoma City, Oklahoma, and San Jose, California - agreed with NASA and PTI to commit local resources and time to test the applicability and feasibility of Landsat satellite remote sensing and digital image processing technologies for local land use planning. Local planners from each jurisdiction were to receive training in remote sensing and operation of a computer image processing system. Each jurisdiction was to develop an internal capability for processing satellite data and conduct demonstration application projects for a 15 month test period.

In this section the experience of the local governement participants is discussed. To provide background for the Landsat applications the characteristics of each jurisdiction are discussed, including: the organization, size, and mission of the local planning departments; purpose, history, and land use planning processes; and the planning information needs and methods. The objectives, approach, results, and assessments of the local Landsat demonstration projects are discussed.

In Section 4 a longer case study of Oklahoma City is presented. Oklahoma City with its large geographic area (621 square miles) and large amounts of undeveloped land is typical of local government jurisdictions which could best utilize Landsat remote sensing. Moreover, the institutional arrangements established during the Landsat project suggest several factors and issues important to transferring satellite remote sensing applications to local governments.

3.1 Atlanta, Georgia

In January 1974, Atlanta's city government was restructured under a new charter from the Georgia General Assembly. The new charter enacted a strong-mayor form of government and provided for members of the policymaking City Council to be elected by districts rather than at-large. Through a companion Reorganization Ordinance, the administration functions of 26 departments were consolidated into nine departments. Each department is headed by a Commissioner appointed by the Mayor and confirmed by the City Council.

One new agency created by the administration's consolidation was the Department of Budget and Planning. The Department is mandated with preparing the Comprehensive Development Plan and the Executive Budget, administering the zoning ordinance, and preparing special studies for the Mayor and Chief Administrative Officer. (CAO). The Department is divided into two bureaus, each headed by a Director, The Bureau of Budget Policy and Evaluation and the Bureau of Planning.

The Atlanta Bureau of Planning is organized into three divisions - Social and Economic Planning, Physical Planning, and Zoning Administration - plus administrative support and research and information support groups (Table 3.1). The two planning divisions are further broken down into nine program sections corresponding with elements of the Comprehensive Development Plan. The Bureau of Planning is responsible for preparing the Comprehensive Development Plan, implementing the neighborhood planning process, preparing special studies and reports for the Mayor and City Council, and administering the City's zoning and subdivision ordinances. In fiscal year 1978, the Bureau had 64 positions and an operating budget of $674,873.

The 1974 Atlanta City Charter mandates that planning be an integral part of the City's administration. The Charter mandates the Mayor to "have a Comprehensive Development Plan of the City of Atlanta prepared and maintained to be

TABLE 3.1

ATLANTA BUREAU OF PLANNING

COMMISSIONER: David Rivers (Leon Eplan)

DIRECTOR: Collier Gladdin

PI: Wistar Harmon, Steve Grilli

TA: (Larry Madsen)

STAFF: 64 Authorized Positions (FY 78)

BUDGET: $674,873 (FY 78)

ORGANIZATION AND FUNCTIONS:

Social and Economic Planning	Physical Planning	Research Methods	Zoning Administration
• Housing	• Land Use	• Parcel Information System	• Rezoning Applications and Review
• Human Services	• Transportation		• Subdivision Applications
• Public Safety	• Parks		• Annexations
• Economic Development	• Urban Design		• Zoning Code Revisions
• Environment	• Neighborhood Planning		
• Neighborhood Planning	• Special Studies		
• Special Studies			

used as a guide for the growth and development of the City." The Comprehensive Development Plan must "set forth the comprehensive development goals, policies and objectives for both the city and for individual geographic areas and communities within the city, and ... identify general location, character and extent of streets and thoroughfares, parks, recreation facilities, sites for public buildings and structures, city and privately owned utilities, transportation systems, and facilities, housing, community facilities, future land use for all classifications, and such other elements, features and policies as will provide for the improvement of the city ... over a 15, 5 and 1 year period." The CDP is annually presented to the City Council for adoption before budget preparation begins in July. Charter provisions stipulate that the approved Plan "shall be used as guide for preparation of the City's Capital Improvement Program and Capital Budget." The CDP is, therefore, the legal guide for formulating budget policy and allocation of resources. Each operating City department contributes input in the form of goals, policies, objectives, suggested programs and projects, and projected funding sources.

The Charter also mandates that citizens be provided an opportunity for involvement in the planning process The Neighborhood Planning Ordinance, enacted in 1974, directed the Bureau of Planning to establish boundaries for the designation of 24 Neighborhood Planning Units (NPU). An NPU is defined by the ordinance as a "geographic area either with distinguishing characteristics or in which residents have a sense of identity and a commonality of perceived interests." Under the ordinance Neighborhood Planning Committees (NPC) advise the Department of Budget and Planning in the preparation of each year's CDP. The NPC's are assisted by NPU Planning Teams consisting of two planners each from the two planning divisions of the Bureau of Planning. The Neighborhood Planning Process

was initiated in 1975. First year objectives were the formation of the 24 NPC's; second year objectives, development of "sketch plans" for each NPU; third year objectives, prepare "definitive" plans to be phased into the Comprehensive Development Plan and Capital Improvement Plan Process for fiscal year 1978-79.

The purpose of the Atlanta Landsat program was to "examine ways to utilize Landsat information to improve the performance of city departments without incurring large data collection costs." Several potential applications were identified:

- Preparation of land cover maps to indicate existing land use conditions in the Neighborhood Planning Units. These could be used to aid in the determination of future planning objectives.
- Monitoring land use changes upstream of the city limits to predict run-off and flooding potentials.
- Land cover inventory of Atlanta's proposed Great Park. The Great Park is currently a long stretch of vacant freeway right-of-way. The ground cover inventory could potentially aid in the design of the park.
- Tree cover inventory of forested and wooded areas in Atlanta. This information could potentially be used to schedule leaf pick-up trucks in the Autumn.

The Landsat Project was assigned to Wistar Harmon, Assistant Zoning Administrator, in the Zoning Administration Division of the Planning Bureau. Initial efforts were planned to focus on developing procedures and a general familiarity with Landsat and the ORSER processing system by preparing landcover maps of selected NPU's. Progress was inhibited, however, by the lack of time that Harmon was free to devote to the project -- about 2 to 4 hours per week. In May, two additional persons were hired in the Zoning Division, enabling Harmon to spend more time on the project. One of the new zoning assistants, Steve Grilli, had a good understanding of statistics which speeded up the process of developing procedures for selecting multispectral signatures.

TABLE 3.2

ATLANTA LANDSAT APPLICATIONS

Application	Requirements	Potential Uses	Results
• Neighborhood Planning	• Land use maps for 24 NPU's • Tabulate acreage by NPU • Distinguish residential densities	• Communicate with community groups • Correlate with zoning categories • Correlate with socio-economics (neighborhood quality) • Traffic generation modeling	• Level I land cover classification developed for • Buckhead NPU Signatures used to create city-wide classification
• Tree Cover Inventory	• Map forested areas by three type • Determine rate and timing of leaf fall	• Schedule leaf pickup trucks • Park design	• Not attempted
• Urban Flood-plain & Water-shed monitoring	• Landcover change detection in flood-plain • Calibrate land cover with runoff, flooding, erosion, pollution	• Monitor new development upstream of city limits • Control floodplain development • Storm sewer planning	• Not attempted
• Automated Map Data Pase System	• Integrate census zoning, parcel, land use data • Graphics, mapping report writing functions • Support planning/ projection models	• Neighborhood planning • Comprehensive development planning • Zoning review • Transportation planning • Special studies • Urban research	• Multi-agency advisory group established to develop system requirements and recommendations • Senior cartographer position created by city council to worl on development of a system

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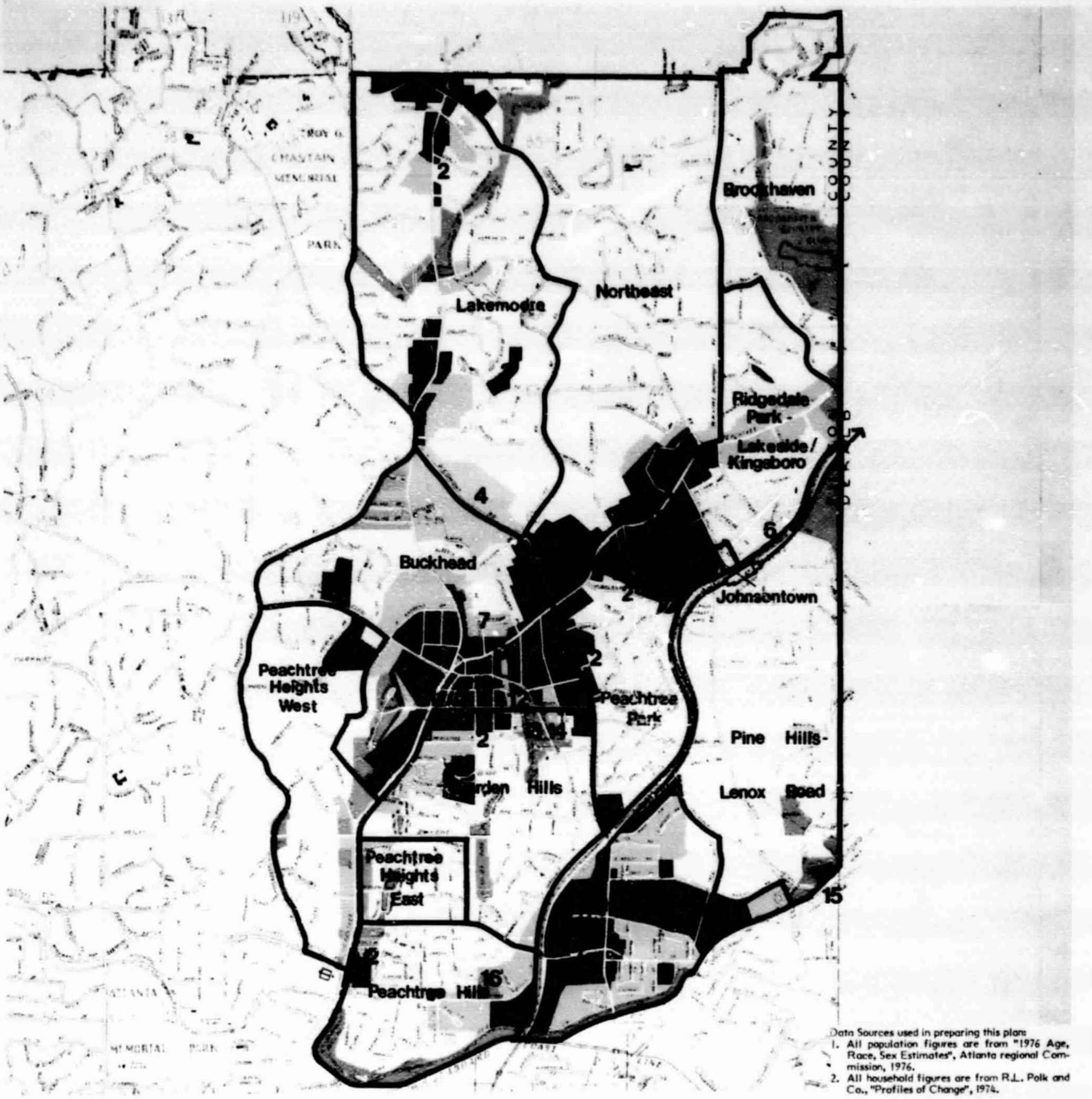
The final results include the NPU land cover map for the Buckhead, Lenox-Phipps area shown in Figure 3.1. Categories are: Residential (yellow); High density residential (tan); commercial/industrial (red); public open space and institutional (green); undeveloped (white); and water (blue). The Landsat map compares closely to the Five Year Land Use Plan shown in Figure 3.2. Major differences are in the specific residential density values used in the Five Year Plan and the detail in commercial and industrial uses. When ground-truthed with existing land cover, the Landsat classification was estimated to be 90 percent accurate but no confidence levels were estimated.

One advantage of Landsat digital mapping is that large areas can be classified once an initial area has been interpreted. The Landsat multispectral signatures used to classify the Buckhead, Lenox-Phipps NPU were also used to produce a city-wide land cover map (Figure 3.3). There is no city land use or cover map to compare with the Landsat classification. The Landsat map gives an accurate regional overview of urban development in Atlanta. It was not possible to obtain land cover area tabulations for either the NPU or city, because the ORSER system has no practical mechanism for specifying the irregular boundaries of the NPU or city limits.

The Landsat research had a direct effect of focusing attention on the Bureau of Planning on its need for greater data coordination. Interest in developing an automated data base and mapping system was revived as a result of the Bureau's involvement with Landsat. Also, Bureau personnel developed a greater understanding of computer precessing techniques and equipment, enabling them to make recommendations for developing an automated mapping system. In November, 1978 the City Council created a new position of senior cartographer in the Bureau of Planning with responsibilities for assisting in the development of an automated mapping system and investigating additional Landsat applications, and the City has prepared proposals seeking funds to support these two objectives.

Figure 3.1 Landsat Land Cover Map of Buckhead, Lenox-Phipps Neighborhood Planning Unit (NPU B)



Data Sources used in preparing this plan:
1. All population figures are from "1976 Age, Race, Sex Estimates", Atlanta regional Commission, 1976.
2. All household figures are from R.L. Polk and Co., "Profiles of Change", 1974.

NOTES

1. Staff Roswell-Wieuca Fire Station.
2. Define and instigate buffers between existing residential areas and adjacent commercial areas.
3. Provide for more year-round utilization of public school facilities.
4. Encourage all office and residential high-rise construction to be as self-contained as possible. Maximum height, 6 floors.
5. Restrict high-rise multi-family residential buildings to the Lenox node and the Lindbergh node.
6. Widen Roxburo Road from Peachtree Road to the Southern Railroad.
7. Support an effort to undertake a BUCKHEAD DEVELOPMENT PLAN.
8. Initiate and complete a comprehensive traffic engineering study of NPU-B and the areas NPU-B impacts.
9. Enlarge and repair the Ida Williams Library.
10. Establish an adequately staffed police precinct within NPU-B.
11. Change traffic signals in Buckhead to free-standing poles, when utility poles are removed.
12. Expand services and programs at the Pharr Road Clinic.
13. Resurface existing roadways and parking areas within Bagley Park and add bathroom facilities.
14. Add general purpose playground equipment in Bagley Park adjacent to the grill locations.
15. Improve north-south traffic from I-85 and Lenox Road to Roswell-Piedmont intersection past the Phipps-Lenox area.
16. Replace existing gymnasium in Peachtree Hills Park with modern facility.

ATLANTA CITY COUNCIL

Carl Ware, President
John H. Calhoun, District 1
Charles Helms, District 2
James Howard, District 3
James Bond, District 4
Morris Finley, District 5
Esther Lefever, District 6
George Cotsakis, District 7
Richard Guthman, Jr., District 8
Arthur Langford, Jr., District 9
Ira L. Jackson, District 10
Bob Waymer, District 11
Hugh Pierce, District 12
E. Gregory Griggs, Post 13
Marvin Arrington, Post 14
Panke Bradley, Post 15
Buddy Fowlkes, Post 16
Q.V. Williamson, Post 17
Jack Summers, Post 18

LEGEND

- 0-4 units/acre Residential
- 5-8 units/acre Residential
- 9-16 units/acre Residential
- 17+ units/acre Residential
- Commercial
- Office
- Industrial
- Institutional
- Parks

NEIGHBORHOOD PLANNING UNIT B · 1979

FIVE YEAR PLAN

Ginger Slaughter, Planner.

BUREAU OF PLANNING
DEPT. OF BUDGET AND PLANNING
CITY OF ATLANTA
MAYNARD JACKSON, MAYOR

0 400 800 1600 2400 4000

Figure 3.2 Five-Year Land Use Plan for Buckhead, Lenox-Phipps Neighborhood Planning Unit (NPU B)

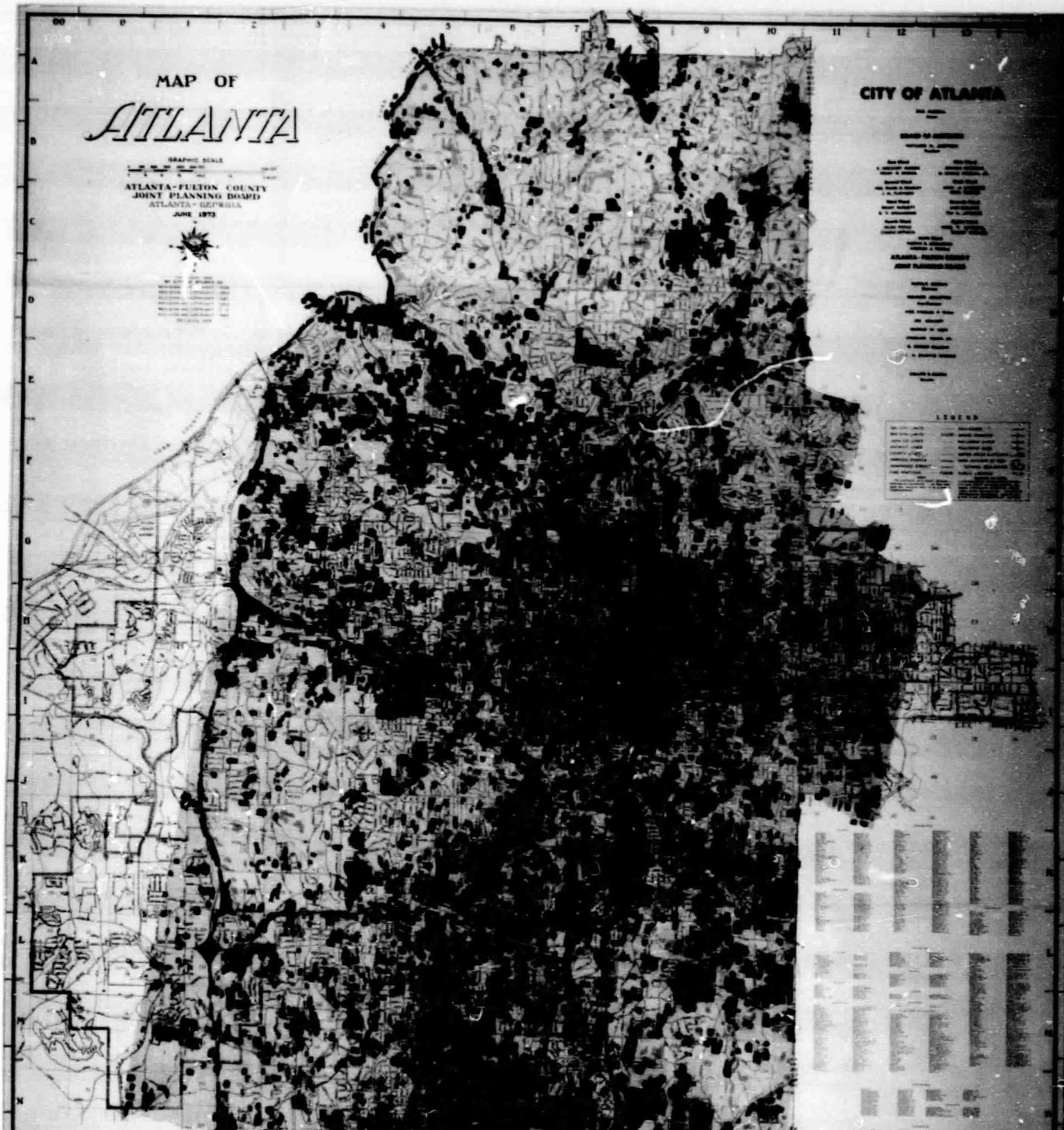


Figure 3.3 Landsat Land Cover Classification of Atlanta, Georgia

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3.2 Henrico County, Virginia

Henrico County, Virginia, is a rapidly urbanizing suburban county. Between 1950 and 1960 its population increased 105 percent, and between 1960 and 1970 it increased 32 percent again to 154,364. Its share of the region's population has increased from 16 percent to 30 percent in twenty years. By 1990 Henrico's population in projected to exceed that of the City of Richmond and all of the other jurisdictions in the Richmond SMSA. The portion of the metropolitan work force working in Henrico is predicted to increase from 16 to 25 percent. This growth will mean 86,000 new people and 48,000 new dwelling units.

To deal with the changing character of the County and to plan for efficient growth, the County in 1974 published a Land Use Plan as a guide for development through 1995. The Plan has three parts: (1) Goals, Objective Areas, and Policies indicating the intent of the Plan; (2) the Plan Map delineating the extent, size, and general location of each land use; and (3) the Phasing Plan proposing the appropriate timing of development in the county. The Land Use Plan is one element of a Comprehensive Plan as required by Virginia Commonwealth law and Federal funding regulations.

The 1974 Plan calls for 21,677 acres of new development. Most of this new development would be residential areas. The biggest percent increase, however, would be for the acquisition of a system of county parks and open spaces (1,346 percent). According to the Plan, Henrico County in 1955 will be 37 percent urban or built up, 12 percent will be held in conservation and 49 percent will be vacant or used for agriculture. Development is to be phased in four Objective Areas: Developed, Transitional, Expansion, and Outlying.

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TABLE 3.3

Henrico County 1974 Land Use Plan Land Use Change Projections, 1973-1995

(acres and percent of County)

	1973	1995	Acres Changed	Percent Change
Residential	21,462 (13.7)	34,893 (22.3)	+13,431	62.5
Commercial	2,011 (1.3)	3,946 (2.5)	+ 1,935	96.2
Industrial	3,002 (1.9)	5,179 (3.3)	+ 2,177	72.5
Public & Semi Public	8,614 (5.5)	10,164 (6.5)	+ 1,550	18.0
Active Recreation	192 (0.1)	2,776 (1.8)	+ 2,584	1345.8
Environmental Protection	19,450 (12.5)	19,450 (12.5)	----	----
Agriculture and Vacant	101,570 (65.0)	79,893 (51.1)	-21,677	-21.3
TOTAL	156,301 (100.0)	156,301 (100.0)	21,677	13.9

The Henrico County Planning Office was responsible for preparing the 1974 Plan and background studies which support the plan. The Planning Office has major responsibilities in the implementation of the Plan policies through the administration of the County zoning ordinance and subdivision codes; preparation of other elements of the Comprehensive Development Plan (Community Facilities, Transportation, Open Space); assistance in preparing

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capital improvements budgets; and preparation of an annual State of the Land Use Plan report. The Planning Office is organized into two functional units and an administrative unit under a Planning Director appointed by the County Manager (Table 3.4). The Current Planning Section has responsibility for daily administration of procedures for rezoning, subdivision of land, places of development, use permits, and zoning appeals, as well as the enforcement of the zoning and subdivision or ordinances. The Advance Planning Section prepares land use, transportation, open space, public facilities, and housing plans; conducts small area studies and special studies for the County Manager and Board of Supervisors; and provides data monitoring. In fiscal year 1977-78, the Planning Office had a staff of 29 - 12 planners, 10 technicians, 7 clerical; No increase in staff was approved in fiscal year 1978-79. The goals developed by the Henrico Planning Office for the Landsat Applications Program were:

- To familiarize County personnel with Landsat capabilities
- To acquire a working knowledge of Landsat data processing
- To produce a land cover classified map of the County
- To evaluate the capabilities of transferring Landsat land cover to drainage basin model and/or computerized data base systems.
- To evaluate other applications of Landsat data to the County.

Responsibility for the Project was assigned to Cheryl Evans a planner from the Advanced Planning Section responsible for the Office's statistical monitoring. Initial processing efforts were hampered by a problem with the County's computerized PBX telephone system which tended to disconnect the connection with the PSU Computation Center. This problem was solved by installing an independent telephone line for the computer terminal in the

TABLE 3.4

HENRICO COUNTRY PLANNING OFFICE

DIRECTOR: Robert Dahlstedt (W. F. La Vecchia)

PI: Cheryl Evans

TA: Larry O'Keefe

STAFF: 29 (12 Planners, 10 Technicians, 7 Clerical)

BUDGET: $529,651 (FY 78)

ORGANIZATION AND FUNCTIONS:

Administration

Current Planning (7 Planners, 10 Technicians)

- Zoning
- Subdivisions
- Plans of development
- Use permits
- Zoning appeals
- Code enforcement

Advanced Planning (5 Planners)

- Interdepartmental assistance
- Transportation planning
- Land use plan updates
- Open space plan
- Public facilities plan
- Housing
- Statistical monitoring and forecasts
- Small area land use studies
- Environmental impact assessments
- Special projects

TABLE 3.5

HENRICO COUNTY LANDSAT APPLICATIONS

APPLICATION	REQUIREMENTS	POTENTIAL USES	RESULTS
Land Use Mapping	• Land use categories defined by state DOT and general plan • Area tabulations by traffic zones, magisterial districts, watersheds, and census tracts • Annual updates	• State transportation planning • Monitor land use policies • Determine land availability • Update comprehensive plan • Regional planning • Open space planning • Small area studies	• Level I landcover categories derived • Areas tabulations performed by ERRSAC • Landcover information used in environmental impact assessment report
Drainage Basin Modeling	• Land cover categories calibrated by runoff potential (imperviousness) • Land cover areas tabulated by drainage basins • Automated input of land cover information into MIT Catchment model	• Predict water quality impacts of land use policies and decisions	• Landsat signatures show correlation with hydrologic factors

Planning Office, but diagnosing the problem involved the efforts of the technology agent and personnel from the PSU Computation Center, computer terminal vendor, telephone company, and County Data Processing Office. A period of four months elapsed before the problem was solved. During that time a number of small analyses were performed, and working knowledge with the ORSER processing system increased.

The Planning Office monitors land use changes and prepares annual land use acreage inventories using Building Occupancy Permits. A technician monthly records land use changes in a Land Use Profile Notebook and updates the Counties subdivision plat maps, plan of development (POD) maps, land use section maps and 1" = 200' scale planimetric maps. Acreage and other information are recorded by magistrial district, traffic zone, census tract, and enumeration district for ten land use categories: single family residential, multi-family residential, commercial service, offices, light industrial, large industrial, public usage, semi-public usage, prime vacant, and conservation vacant. Between 1971 and 1977 the average annual rate of land use change for the county was 950 acres. This land use change monitoring is partially funded by a $2,000 per year contract from the State Department of Transportation. The contract is to provide land use acreage statistics annually by traffic zone as part of the Continuing, Coordinated, Comprehensive Transportation Planning Process (3C Process) required by the 1962 Federal Highway Act to update Regional Major Thoroughfare Plans. The data are also used by the County Planning Office to prepare population estimates and projections, prepare an annual State of the Land Use Plan report, and estimate the availability of land for future development using a Land Consumption Model.

A six category Landsat landcover classification was prepared by the County using the ORSER system in about four months time, once the telephone line problem was resolved. The categories derived include: residential, commercial, heavy vegetation, light vegetation, agriculture, and water. About three weeks of a planner's time, and 63 hours of computer connect time, and 42 minutes of computer processing time were required. Computer charges were about $342, computer terminal costs, about $500, and WATS telephone line charges, about $1,100. Total cost was about $12.00 per square mile for the 244 square mile County.

In order to produce land use or land cover acreage statistics it was necessary to be able to input to the computer the map coordinates of the County boundaries and tabulate the number of Landsat picture elements classified into each category. The ORSER processing system does not have the capability to process the large number of map coordinates required, so NASA's Eastern Regional Remote Sensing Applications Center (ERRSAC) agreed to provide technical assistance in this matter using an interactive digital image manipulation system (IDIMS) and a geographic data entry system (GES). These systems utilize a digitizing table to enter map coordinates defining the boundaries of the magisterial districts, traffic zones, census tracts, and watersheds into a computer. The Landsat image classified by Henrico County was resampled to register with the digitized map coordinates. The picture elements within each district, zone, tract, and basin were then tabulated, and the digital image of the classified Landsat scene and digitized maps were recorded on film to produce a color land cover map (Figure 3.4).

Several difficulties were experienced in trying to digitize the maps and produce the land cover statistics. First, the IDIMS and GES systems had

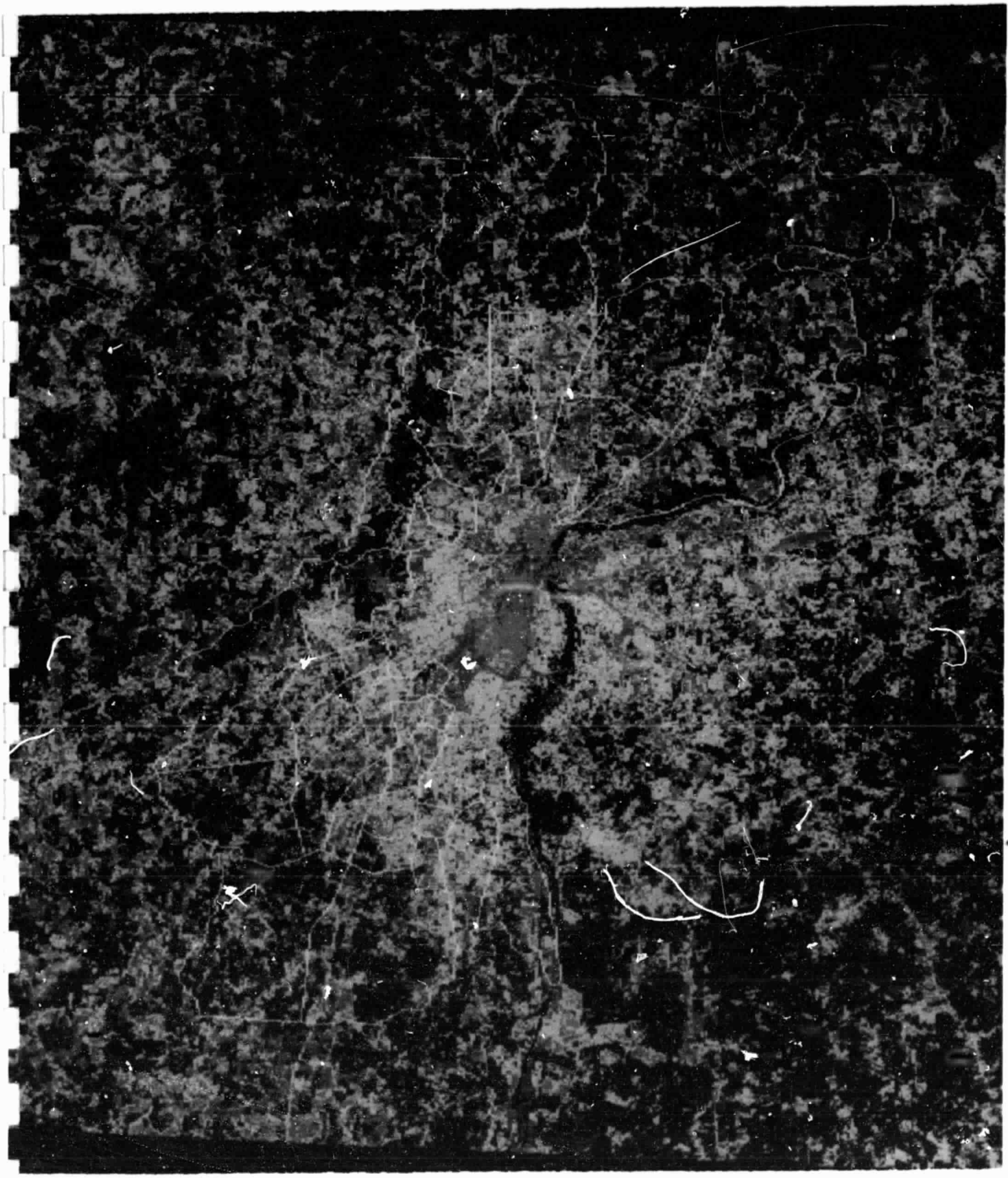

Figure 3.4 Landsat Land Cover Classification of Henrico County, Virginia with Digitized Map Overlay of Traffic Zone

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not yet been accepted from the systems vendor and frequent hardware and software failures occurred. Second, the ERRSAC personnel were still learning to use the systems and had to develop procedures and correct systems documentation as they went along. A total of three months time was required to produce the land cover statistics, however, under operational circumstances the time required should be much less.

Land cover statistics were produced for magisterial districts, traffic zones, census tracts, and watersheds from Henrico County's Landsat classifications. Table 3.6 compares the land cover statistics produced from the Landsat/ORSER/IDIMS-GES procedure and the County's current procedures. Meaningful comparison of the two inventories are difficult because the categories are different. Also the accuracy of neither system is known (in such cases the County's estimates are generally assumed to be correct). It can be seen in Table 3.6 that in this case, the Landsat classification greatly overestimates the residential area (40,908 acres versus 24,614 acres). This was probably due to drought conditions which affected the appearance of agricultural fields at the time of the Landsat image (July 14, 1977). Also, the digital processing technique overcounted the County's area by about 3,200 acres. This is probably the result of errors in the geometric correction of the Landsat imagery and errors in the digital registration of the county maps to the classified image. Looking at Figure 3.4, errors in the registration of the maps to the classified images can be seen; for example, the County boundaries along the southern side shown follow the James River, but do not in the digitized overlay.

TABLE 3.6

Comparison of Land Cover/Use Acreage Statistics for Henrico County by Landsat Digital Image Processing Techniques and Conventional Procedures, July 1977

County			Landsat	
Single Family Residential	22,756.48			
Multi-Family Residential	1,857.18			
	24,613.66	------	Residential	40,908
Commercial Service	2,005.71			
Offices	503.24			
Light Industrial	474.30			
Heavy Industrial	2,929.50			
Public Usage	6,495.53			
Semi-Public Usage	2,496.07			
	14,904.35	------	Commercial/ Industrial	20,003
			Heavy Vegetation	74,989
			Light Vegetation	9,669
Prime Vacant	96,932.58		Agriculture	12,171
Conservation Vacant	19,450.09		Water	1,765
	116,382.67	------		98,594
TOTAL ACRES	156,301			159,505

A second application of interest to Henrico County was the use of Landsat landcover information in a hydrologic model. The County Public Works Department was evaluating implementation of the Massachusetts Institute of Technology Catchment Model (MIT-CAT). The purpose of the model is to identify areas where floods may occur and provide a tool by which the water resource impacts of future development, capital improvement projects, and zoning and land use changes can be predicated. Changing land use from

natural state to one of development means more and faster water runoff due to increased imperviousness and investment in drainage systems. As a result, flooding problems increase, less water recharges the ground-water supply, water contamination due to sediment and street residues increases. Remedial action involves investment in flood control, storm sewers, and wastewater treatment facilities. Preventative measures include land use controls to limit development to those types and areas that will minimize increased flooding and keep pollutants from stream channels.

Traditionally, functional land use information has been used in hydrologic models as a surrogate measure of the actual surface cover of the ground and such characteristics as imperviousness. The landcover information derived from Landsat is more closely related to the character of the ground surface and therefore can potentially be used as input to hydrologic models. The Landsat landcover derived by the Henrico Planning Office was not actually used in the MITCAT model, however. The Public Works Department had not at the time made the decision to implement the model. In addition, modification of the model would have been required to calibrate the model to the Landsat data and develop a method for automatically inputting the Landsat digital information into the model in the network format required. An analysis was made of Landsat spectral values (gray levels) and a "C-Factor" map prepared for the MITCAT model. C-Factors are a hydrologic parameter related to imperviousness and derived from interpretation of land use and zoning maps. Figure 3.5 shows the relationship between the Landsat gray level values in two band widths compared to a sample of C-Factor values picked off a map. The relationship is generally linear, suggesting that a ratio of the two Landsat brandwidths could be used to estimate imperviousness.

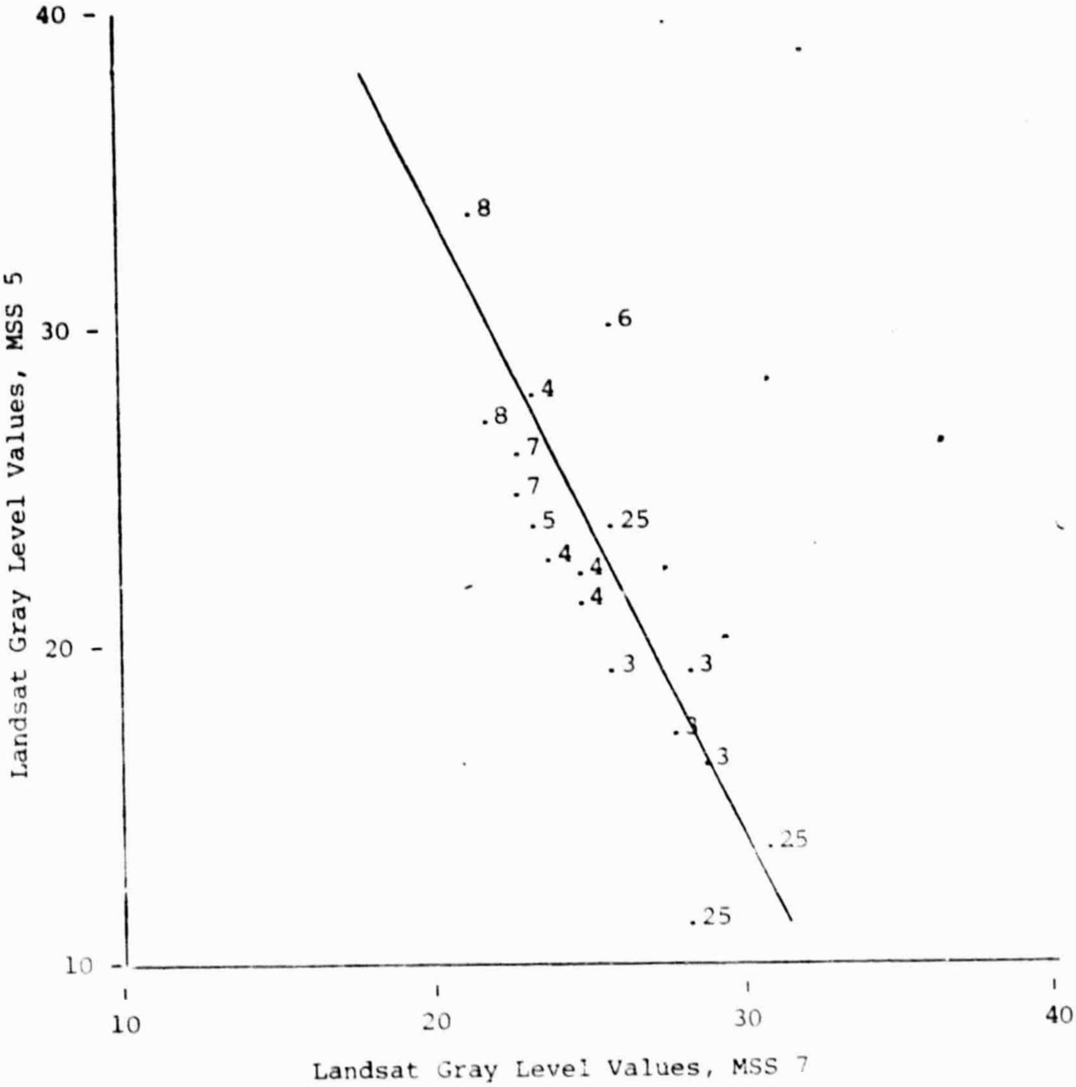

Figure 3.5 Relationship Between Landsat Gray-Level Values and C-Factor Values

The County did use the Landsat landcover information in the preparation of an environmental assessment of a proposed park site (Figure 3.6). The Landsat information showed the location and area of various types of vegetation and land uses on and around the proposed site. This information which was featured on the cover of the environmental assessment report was used in applying for state and Federal recreation funds to acquire the site.

3.3 Minneapolis, Minnesota

No demonstration project was initiated by Minneapolis. It dropped out of the Landsat Applications Program shortly after a newly elected administration took office in January, 1978. Under a City Charter amendment that also took effect then, the City Planning Department, which was to have conducted the Landsat project, was moved from the City Controller's Office to the Mayor's Office. A new Planning Director was appointed by the Mayor with a mandate to prepare a new Community Development Plan for the City. The Community Development Plan had been a campaign issue in the election. In the resulting repriorization of work programs and schedules, the decision was made not to pursue the Landsat project. The experimental nature of the Landsat program, and its connection with the previous administration caused it to be dropped from the Department's list of priority projects.

As well as illustrating the political nature of technology transfer to cities, Minneapolis has several physical characteristics which suggest circumstances where satellite remote sensing may not be an appropriate technology. The incorporated city limits of Minneapolis are only 58 square miles, thus the economics of scale which make satellite remote sensing beneficial in large areas cannot be achieved. Moreover, the city land area has been completely developed since the 1940's. Most

Figure 3.6 Landsat Information used for Henrico County Environmental Assessment of Proposed Park

LANDSAT

```
PROGRAM: CLASS
DATE AND TIME: 09/19/78  18: 9
TAPE NAME: RS0248, FILE: 1
PAGE 1 OF 1

BLOCK SPECIFICATIONS
--------------------
   BEGINNING LINE    805
      ENDING LINE    841
BEGINNING ELEMENT   1685
   ENDING ELEMENT   1730
   LINE INCREMENT      1
ELEMENT INCREMENT      1

GEOMETRIC CORRECTION PARAMETERS FROM THE ID RECORD
--------------------------------------------------
LINES & COLUMNS OUTPUT PER INCH BY DISPLAY DEVICE:  6.0   10.0
MAP SCALE: 1 TO   24000.
LATITUDE: 37.38
NO ROTATION REQUESTED.
FINE CORRECTION FACTORS:   1.020   1.020
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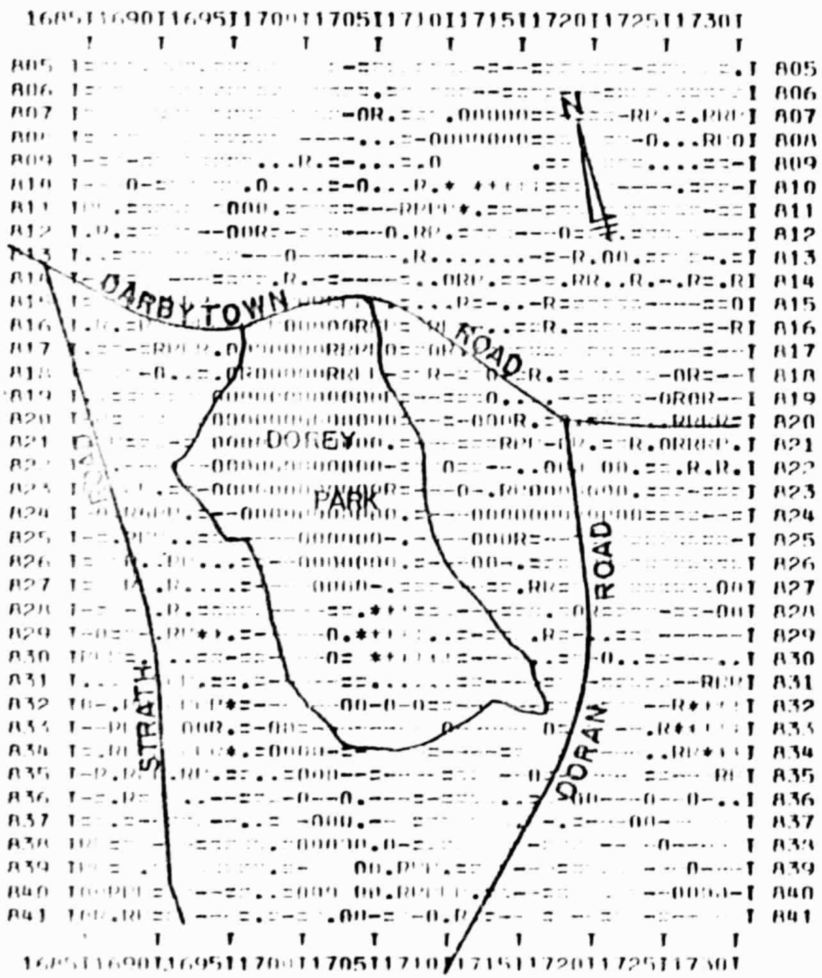

DOREY PARK

	LAND COVER	PERCENT OF TOTAL PARK
	FOREST	42.0%
–	HARDWOODS	25.0%
=	SOFTWOODS	11.5%
•	MIXED	6.0%
R	RESIDENTIAL	8.0%
O	AGRICULTURE	44.0%
*	MINED AREA	5.0%
(blank)	WATER	0.50%

land use changes in the last ten years have been due to redevelopment or abandonment, neither of which would be detectable from satellites. Lastly, the Minneapolis-St. Paul area has a unique regional government, the Metropolitan Council, which has responsibility for many regional planning functions including transportation, water and sewer, and land use. Thus many regional concerns that might utilize satellite data collection techniques are not the responsibilty of the City Planning Department in Minneapolis' case.

3.4 Oklahoma City, Oklahoma

Unlike most cities, Oklahoma City was never small. Founded in a land rush in 1889, it began with a population of 6,000 in a single day. Population growth was slowed briefly by economic depression and drought in the 1920's, but after World War II new industry brought new growth. Between 1940 and 1970 the city's limits increased from 25.9 square miles to 649 square miles as the city sought to gain control of the region's water reservoirs and developable land. The second largest municipal area in the United States, Oklahoma City is characterized by a large urbanizing fringe. Only about 25 percent of the city is developed; 75 percent of the land area is vacant or is used for agriculture.

Since 1977 The Oklahoma City Department of Planning has been a department within the superdepartment of Management Services. Planning is organized into three divisions under a Planning Director: Administration Economic Development, and Urban Design. The Department is responsible for housing and conservation design services, select area planning, economic development planning and data monitoring and research. Zoning, subdivision controls, special use permits and other adminstrative functions are handled by the Community Development Department. In fiscal years 1977-78 and 1978-79 the Planning Department had

TABLE 3.7

OKLAHOMA CITY PLANNING DEPARTMENT

DIRECTOR: (Norman Standefer)

PI: Roy Reynolds, Gerald Johnson

TA: James Carter, Coordinator Management Services

BUDGET: $444,378 (FY '78) $522,552 (FY '79)

ORGANIZATION AND FUNCTIONS:

ADMINISTRATIVE DIVISION

URBAN DESIGN DIVISION

- Housing and Conservation Section
  - Design services for housing conservation and rehabilitation programs
  - Design services for special studies
- Select Area Planning Section
  - Identify problems and conflicts at neighborhood levels
  - Insure public involvement in planning process
  - Develop select area plans

ECONOMIC DEVELOPMENT DIVISION

- Economic Development Section
  - Overall economic development plan
  - Foreign trade zone study
  - Industrial site reports
  - Industrial opportunity study
  - Assist local development companies
  - Prepare Federal grant applications
- Data Monitoring and Research Section
  - Data support - Land use inventory select area resource documents, population estimates
  - Maintain Data Bases
  - Research - building permit inventory, population/housing study, remote sensing, automated data base
  - Outreach/Data assistance

22 authorized positions and a budget of $444,378.

In 1977, the City Planning Department published a Comprehensive Plan for Growth Management and Community Development. Two previous comprehensive plans had been prepared by consultants in 1931 and 1949. The 1977 plan had been initiated in 1975 when the city realized that it severely constrained fiscal resources might not be sufficient to cover the costs of providing services, streets, sewers and schools to uncontrolled future development. The major objectives of the 1977 Plan are (1) to preserve the remaining undeveloped land in the city by reducing land consumption of new development by 40 percent, and to conserve the existing housing stock by revitalizing 27,200 dwelling units by the year 2000. The City has estimated it will save $250 million in capital improvements costs with this "conservation" policy during the next 25 years.

In order to implement and detail the long-range goals and policies of the 1977 Comprehensive Plan at the neighborhood and program level, the Select Area Planning Process was established. Through the Select Area Planning Process, citizens groups and the Urban Design Division of the Planning Department prepare strategy documents recommending city actions and programs concerning land use, zoning, capital and service improvements, community development, economic development for each of the city's 45 designated planning areas. Once adopted by the neighborhoods, the Planning Commission and City Council, the Select Area Plans are implemented by the cities 10 executive departments.

The Landsat Applications Project was undertaken to determine if Landsat could meet the information needs of the Data Monitoring and Research Section of the City Planning Department. This Section is responsible for maintaining the City's physical, demographic, and economic data base for providing data support services to city departments and other public and private groups.

At present, the primary client is the Select Area Planning Process. For each planning area, the Data Monitoring and Research Section prepares a Resource Document containing an inventory of demographic, land use, zoning, housing, business and industry, and urban services and facilities.

The Data Monitoring and Research Section's data base presently consists of population, economic, housing and land use information from several sources. Maps are maintained at four scales: 1"=200', 1"=400', 1"=6,000' and 1"=12,000'. Black and white aerial photographs for 1968 and 1976 are also maintained. In 1979, the Department completed a three year project to prepare the first complete city-wide land use inventory in 30 years. Approximately 20 man-years of effort were required to complete the land use survey. Automated data base services include the annual R.L. Polk Profiles of Change and address matching.

The City Planning Department with the concurrence of interested officials from the State, Conservation Commission, Soil Conservation Service, and University of Oklahoma, identified three potential applications of Landsat in Oklahoma City: monitoring urban growth; monitoring watershed land use changes; and developing an automated urban information system (Table 3.8). Growth Monitoring was selected as the most feasible and most important for initial demonstration. The objective of the growth monitoring demonstration was to use successive digital Landsat images to distinguish urban from agricultural land uses. Operationally, this information could be used to determine rates of agricultural land consumption, monitor the effectiveness of the Comprehensive Plan in conserving growth, alert officials about new growth, and assist in maintaining an up-to-date land use inventory.

From April through July, 1978, the OKC Planning Department used the ORSER system to analyze two test areas within the city from a June, 1977 Landsat image.

TABLE 3.8

OKLAHOMA CITY LANDSAT APPLICATIONS

APPLICATION	REQUIREMENTS	POTENTIAL USES	RESULTS
• Monitor Urban Growth	• Distinguish urban from rural land uses • Annual updates • Area tabulations by planning areas, subregions, and zones • Map outputs at scales of 1" = 12,000' and 1" = 6,000'	• Update land use inventory • Determine rates of agricultural land conversion • Monitor effectiveness of general plan • Forecast fiscal impacts of new development	• Level I land cover classification with ORSER • 1977 and 1974 images classified on ERL/CVIPs
• Monitor Watershed Land Use Changes	• Establish baseline watershed land use/cover inventory • Annual updates • Area tabulations by watershed • Monitor water quality and quantity • Correlate land use/cover to water quality and quantity	• Monitor city water supply from reservoirs outside city limits	• Not attempted
• Automated Urban Information System	• Integrate demographic, economic, land use, parcel, and remote sensing data	• Data support to City's planning and community development programs	• Not attempted

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The analysis was performed by Gerald Johnson, an administrative aide, under the supervision of Roy Reynolds, a senior planner in charge of the Data Monitoring and Research Section. The result was a seven category land cover map (Figure 3.7). Land cover categories were water; urban/residential; paved surfaces/commercial; prairie; wetlands; agriculture/prairie; bare ground/ fallow fields. Average accuracy of the classification was estimated by the OKC Planning Department to be 78 percent.

About 80 hours of computer connect time and 40 minutes of computer processing time were utilized to derive the results in Figure 3.7. Cost of the computer time (not counting telephone charges and the cost of the remote computer terminal) was less than $400. In addition to the time spent processing the Landsat data on the computer, the Planning Department estimated that 80-100 hours of personnel time were required to gather ground truth information and interpret the computer output.

The time required to develop the land cover information using the ORSER processing system was considered by the Planning staff to be too long to be practical for operational use. For example, many tedious hours were required to hand color the computer map printouts before they could be interpreted. Also, the planning staff did not understand the statistical processes being utilized by the ORSER programs and, therefore, lacked confidence in the results.

Through a grant to the University of Oklahoma, the OKC Planning Department was also able to try the urban monitoring application on a second image processing system at NASA's Earth Resources Laboratory (ERL) in Slidell, Louisiana. The ERL ERDAS (Earth Resources Data Analysis System) system is different from the ORSER system in that it is interactive rather than remote batch; processing results are displayed in seconds rather than minutes; processing results are displayed on a color television monitor (CRT) rather than

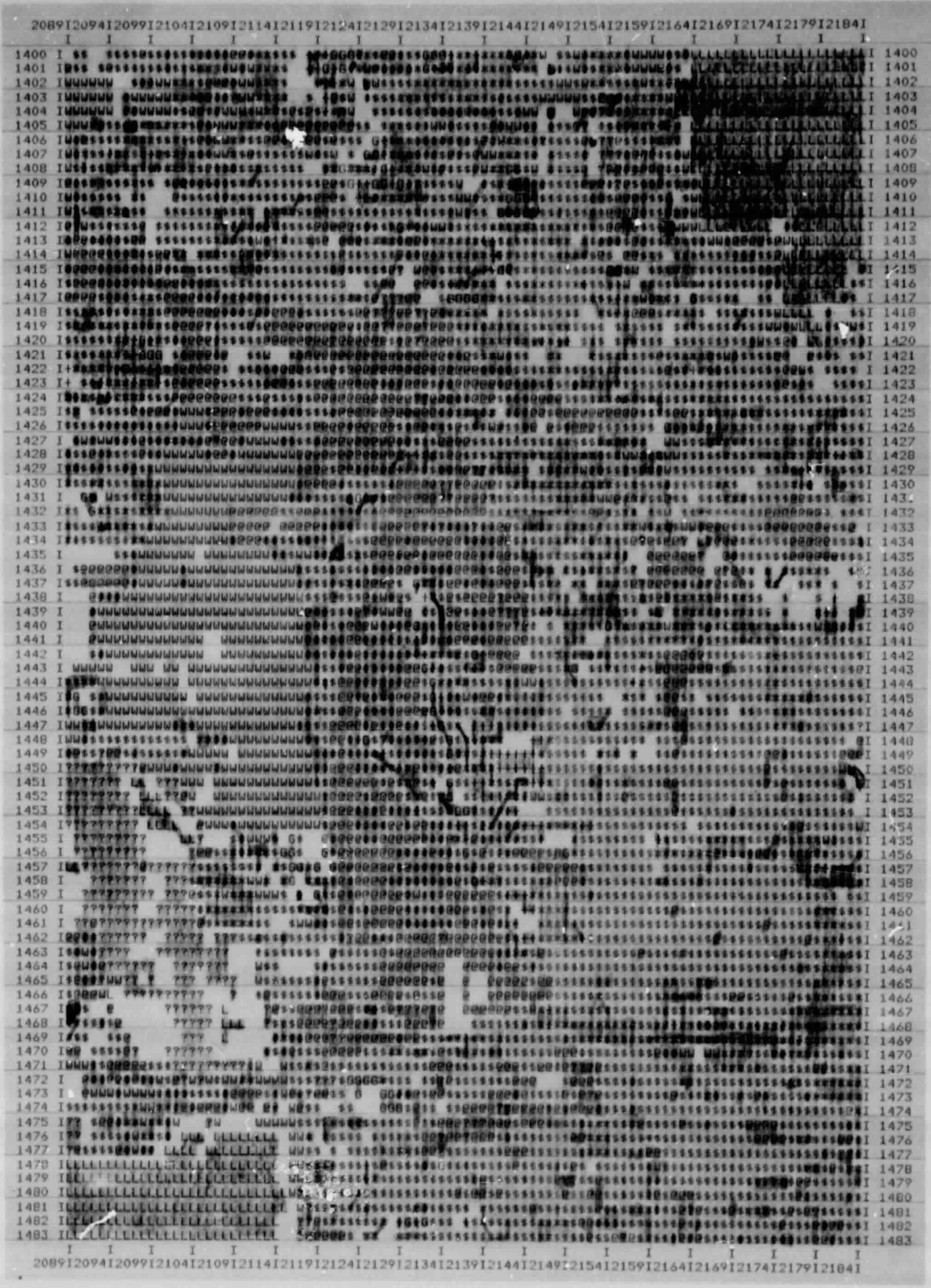

Figure 3.7 Landsat Land Cover Classification of a Portion of Northwest Oklahoma City using ORSER System

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a line printer; and different algorithms are used to extract the multispectral signature statistics for land cover types and classify the image. Commercially available image processing systems similar to ERDAS cost $150,000-$250,000 or can be rented with operators for approximately $200 per hour.

Approximately a week was required to classify two Landsat images using the ERDAS system operated by NASA support personnel -- the June, 1977 image OKC had previously classified on the ORSER system and a July, 1974 image. Figure 3.8 shows the land cover classifications produced on ERDAS. The area covered is approximately the same as that covered in the ORSER system classification in Figure 3.7. The land cover categories in the ERDAS classification were interpreted to be: bare fields/commercial/industrial; residential; asphalt/bare ground (1974 only); fallow fields (1974); agriculture (3 classes in 1974, 2 classes in 1977 image); water; and wetlands. Differences in the ERDAS and ORSER classification of the June, 1977 Landsat image are caused by the use of different multispectral signatures and different processing algorithms.

The two ERDAS classifications were evaluated by the OKC planning staff for their ability to indicate land use changes. The 1977 classification shows more yellow (residential) and red (commercial/industrial) than the 1974 classification, potentially indicating new development. However, both classifications contain misclassifications which make it impossible to determine precisely where changes have occurred. For example, in the 1974 classification the yellow areas are generally residential but contain some agricultural fields as well. In the 1977 classification, the residential category also contains misclassified agricultural fields and an airport, which was separately classified in the 1974 image, has been classified residential. The 1977 classification also suggests

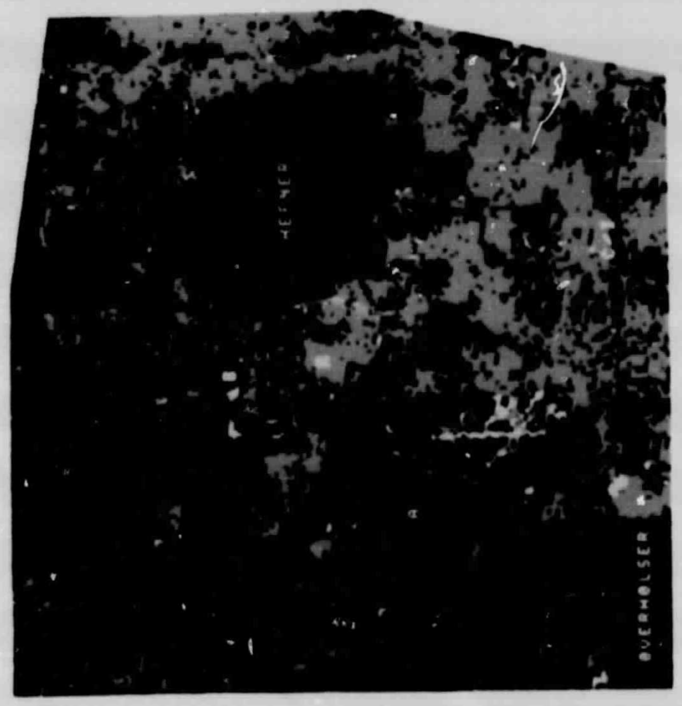

Figure 3.8 Land Cover Classifications of 1974 and 1977 Landsat Images of **Portion of Northwest Oklahoma City using ERDAS System**

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a large increase in commercial and industrial land uses, when in fact, most of the apparent changes are due to bare or fallow fields misclassified as commercial land (red).

The two ERDAS classifications illustrate several problems with using Landsat data for change detection. First, at certain times of the year different land uses may have similar land covers and therefore similar spectral signature values which will result in misclassifications. Second, classifications of the same area from images acquired by the satellite at different dates, or images processed using different procedures or classification algorithms may result in maps with different categories. This may be particularly true when an unsupervised cluster analysis algorithm is used to classify the images as was done on the ERDAS system. Lastly, the accuracy of a change detection determination made from two independently classified images will equal the product of the accuracies of each of the individual classifications. That is, two images each with an overall accuracy of 90 percent would produce change results with only an accuracy of only 81 percent. While this last problem is not unique to Landsat but would exist with any data collection methodology, the errors can be reduced if the images are processed together as a composite rather than separately processed.

3.5 San Jose, California

Since the end of World War II San Jose has experienced dramatic economic changes and rapid population growth which have altered the size and form of the City. The structure of the city's economy has been transformed from an agricultural and transportation center to a financial, office, and high technology research and manufacturing center. This economic growth brought large inmigrations of young, highly skilled, highly paid workers and their

families to the region. Between 1950 and 1970 the city's population grew nearly 500% from 95,280 to 459,913. San Jose's growth as a percent of Santa Clara County's growth which was 33% in 1950, grew to 45% in 1970. Although the greatest period of growth was the 1960's, the population growth has continued in the 1970's. Between 1970 and 1976 San Jose was the fastest growing city in the United States with a population over 500,000. San Jose's population increased 25% in six years to approximately 573,000--an average increase of 19,000 persons annually.

Along with the tremendous growth, San Jose, like many other California cities pursued an agressive policy of annexation during the 1960's. The City's incorporated area grew from 27.62 square miles in 1955 to 142.70 square miles in 1970. In 1970 San Jose adopted a set of Urban Development Policies dealing with the timing and staging of development. The Urban Development Policy and the related Annexation Policy were ammended in 1972 and again in 1974. The Urban Development Policy had three major impacts:

1. Agreement was reached with the County of Santa Clara and the Local Agency Formation Commission (LAFCO) that urban development requiring municipal services should not be allowed to develop in the unincorporated areas of the County.
2. The City Annexation Policy was amended to be consistent with, and related to the goals of the Urban Development Policy. Unincorporated lands within the Urban Service Area were to be given highest priority for annexation.
3. The concepts of Urban Service Areas and Urban Reserve Areas were established. The Urban Service Area consists of existing urban development areas and vacant agricultural land, either incorporated

or unincorporated, within the City's sphere of influence, which are served by existing urban facilities, utilities, and services or are proposed to be served by urban facilities, utilities, and services in the City's adopted five-year Capital Improvement Program. The Urban Service Area is divided into two categories:

Urbanized Area - This includes all developed areas within the Urban Service Area.

Urban Expansion Areas - These areas consist of vacant and agricultural land within the Urban Service Area proposed for urbanization in the future and served by existing or proposed service and utilities. Vacant and agricultural land within the urban expansion area are categorized according to "commitments" of uses; vacant public committed land, vacant private committed land, vacant Williamson Act Land (land under contract to the City through the California Land Conservation Act of 1965), vacant industrial reserve land, and vacant non-committed land.

The Urban Reserve Area consists of lands which are generally not readily accessible to utility extensions or where development of community facilities is not programmed. These areas generally contain no urban development and generally no urbanization is expected in the next 15-year period.

In 1975 a General Plan was adopted by San Jose containing the following state mandated elements: land use, circulation, housing, conservation, open space, seismic safety, noise, scenic highway, and safety. The General Plan is the adopted statement of policy for the physical development of the community. As such, it represents the City's intent as to the amount, type, and phasing of development needed to achieve the City's social, economic and environmental goals.

Growth was the central issue in the development of the 1975 General Plan. The General Plan recognized that the amount of available land for urban growth was finite. The General Plan estimates that by 1990 the City's population will increase from approximately 542,000 in 1975 to approximately 728,000 in 1990, while the population within the City's sphere of influence

is projected to increase from 643,000 to approximately 780,000. San Jose's share of Santa Clara County's population which was 45% in 1975 was projected to be 49% in 1990. This growth will be accommodated by development of about 7,500 units per year (this is a decrease from the 8,000 dwelling units annual average authorized between 1970 and 1974). Land consumption over the fifteen-year period was estimated to be about 1,600 acres per year compared to 1,900 acres urbanized annually from 1970 through 1975. The General Plan estimated that the 10,680 acres suitable for development in the Urban Service Area was sufficient for 6½ years of future growth.

The General Plan had five major recommendations:

1. Revision of the City Zoning Ordinance to conform with the General Plan.
2. Incorporation of the Urban Development Policies into the General Plan. The Urban Development Policies are implemented through a development review process and the capital planning process.
3. Approval of new zoning for residential development to be based on a finding that it will constitute a net benefit to the City. The net benefit determination consists of economic, fiscal, social, and environmental findings that demonstrate that the benefits of a project to the community will outweigh the disbenefits.
4. Establishment of Urban Service Programs to identify service deficiencies in developed areas and develop sequencing plans for providing services to developing areas.
5. Preparation of Master Environmental Impact Reports (MEIR's) for the City's 15 planning areas to enable the City to evaluate cumulative, area-wide effects of development.

An annual review and amendment process was established to update the General Plan. The annual review is timed to provide input to the Capital Improvement Program and Urban Service Programs.

The San Jose City Planning Department's mission is to serve the City Council, the Planning Commission and the Administration by recommending, developing and administering policies, plans, and programs that guide and direct the physical, social and economic development of the City. The Department is organized into three divisions: Administration, General Planning, and Zoning--of which Zoning is the largest.

The Zoning Division is responsible for administration of land use regulations through application review process including rezoning applications, plan development permits, site development permits, tentative maps, conditional use permits, variances, exceptions, and adjustments. In addition the division drafts new land use regulations, revises existing ordinances, and conducts short-range land development policies for the City Council, Planning Commission, and City Manager. The main activity of the General Planning Division is the semi-annual amendment of the General Plan. Other tasks include: recommend changes in the Urban Service Area boundary, develop energy conservation policies, prepare area plans, carry out the City's annexation program, participate in regional planning activities, maintain land use/housing and population estimates, and review pending legislation. Since 1975 the Planning Department's administrative workload has increased 40 - 50% and the number of authorized personnel has decreased 12%. To keep up with this increased work load the review process has been streamlined, mid-year General Plan review has been eliminated, other programs have been transferred to other city departments, and staff have been transferred from general planning to zoning administration. The Planning Department's $1,168,000 annual budget is one percent of the City's annual general purpose budget.

TABLE 3.9

SAN JOSE PLANNING DEPARTMENT

DIRECTOR: John Hamilton

PI: John Berg (Gary Zouzoulas)

TA: Monroe Postman

STAFF: 39 Planners, 14 Technicians, 13 clerical (FY '78)
8 positions lost and 7 positions vacant in FY '79

BUDGET: $1,221,000 (FY '78); $1,168,000 (FY '79)

ORGANIZATION AND FUNCTIONS:

ADMINISTRATION DIVISION (13 positions)

GENERAL PLANNING DIVISION (23 positions)

- General Plan
  - Update general plan
  - Vacant Land inventory
  - Population & housing estimates & projections
  - Annual Urban Service area review
  - Special area studies
  - Plan element studies (energy)
  - Annexations
  - Review county general plan revision
  - Regional planning activies
- Special Studies
  - Jobs/housing blanaced development study
  - Airport vicinity plan
  - Litigation
  - Feasibility studies
  - Special area studies

ZONING DIVISION (30 positions)

- Zoning Reports
  - Rezoning applications
  - Planned developments
  - Subdivisions
  - Zoning code revision
- Design
  - Site development permits
- Environment
  - Environmental impact reviews
  - Special permits

For planning purposes San Jose is organized into 15 planning areas. These planning areas are based on identifiable neighborhoods and boundaries and do not conform to Census tract boundaries. As of January 1, 1979 the City Charter was amended to allow for elections by 10 councilmatic districts beginning in 1980. These councilmatic districts will be based on population. Henceforth, City Planning data will be collated by councilmatic district rather than planning areas. City Planning data are also reported for 490 Traffic Analysis Zones for the State Highway Department which uses the information in trip generation models.

The Landsat project in San Jose was begun in April, 1976 under NASA Contract NAS5-22412 when a six month test of the ORSER system was made. Gary Zouzoulas, a planner in the Zoning Division, was given three days of ORSER instruction at Goddard Space Flight Center and prepared a Landsat land cover classification. At the time, the ORSER terminal was located in another city department. A June 28, 1974 Landsat scene was used; ground truth was obtained from June 8, 1974 black and white aerial photographs (1:24,000 scale).

A ten mile square study area in east San Jose was selected as a demonstration. The study area was selected because the area contained a variety of land uses--residential, commercial, industrial, open space, suburban development, agriculture, urban fringe, and unurbanized hillsides--and because the area has a high potential for future urban expansion. After experimenting with several ORSER techniques, 29 multispectral signatures were derived representing 11 land cover categories: Mobile Home Parks, Industrial/Commercial Buildings, Residential, Industrial/Commercial, Parking Lots, Golf Courses, Riparian Habitat, Orchards, Rangeland/Open Space, Excavated Areas/Barren Areas, and Water. As shown in in Table 3.11 the Landsat land cover classification contained a mix of functional land uses in each category. Major sources of

TABLE 3.10 Maps and Map Scales Utilized by San Jose Planning Department

Scale	Maps
1:62,000	Santa Clara County Base Map
1:48,000	Roads, Sphere of Influence, Generalized Land Use
1:36,000	Planning Areas, Urban Service Area
1:24,000	Topographic, Alguist Priolo Hazards, Functional Land Use
1:12,000	General Plan Working Map, Planning Areas, Holding Capacity, Hazards, Zoning (reduced)
1:6,000	Zoning, Land Use Changes

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TABLE 3.11 CHARACTERISTICS OF SAN JOSE LAND COVER CATEGORIES

Category Number	Primary Characteristics	Other Characteristics
1	Mobile Home Parks	Freeway interchanges/Industrial warehouses/Quarries/Bright commercial and industrial buildings/Water towers
2	Industrial/Commercial Buildings	Roadway pavement/Strip development/Large buildings with minimal landscaping/Apartments/Bright parking areas/New construction/Greenhouses/New residential with lawns and no trees
3	Residential	Orchards with moderate to sparse tree cover/Agriculture with some vegetation
4	Industrial/Commercial	Parking area pavement/Dried field/Dirt areas/Outdoor storage areas
5	Parking Lots	Dark buildings/Roadway and freeway pavement/Plowed field
6	Golf Courses	Any well watered turfed area/School yards/Parks/Stadia/Athletic fields/some agricultural row crops
7	Riparian Habitat	Very dense tree cover in residential areas/Hillside oak and dense shrubbery
8	Orchards	Residential with tree canopy/Vineyards/Agriculture row crops
9	Rangeland/Open Space	Dirt field/Roadway and freeway shoulders/Interchanges/Fields of swept hay/ Dried areas with few trees/New residential construction
10	Excavated Areas/ Barren Areas	Rangeland/Roadway and freeway shoulders/Interchanges/Orchards and vineyards with minimal vegetation/Foundation and grading for new construction.
11	Water	Dark plowed fields/Objects with very low reflectivity.

errors were caused by confusion of residential areas and orchards and mobile home parks and freeways.

A map of the eleven categories was made (Figure 3.9). A major problem with the map was misregistration with 1:24,000 scale maps caused by insufficient ORSER geometric correction of the Landsat image. The map was estimated to be 80 percent accurate. A total of 50 hours of computer connect time and $730 in computer charges was required to develop the map.

A second land cover map was generated by Zouzoulas for an Airport Vicinity Area Study (Figure 3.10). This map shows the ability to define a polygonal area with ORSER when the polygon is not complex. With this capability it is possible to obtain area measurements for each land cover in the study area. Area tabulations for the Airport Vicinity Area Study are given in Table 3.12.

In November, 1977 when the second PTI/NASA Landsat project began, Gary Zouzoulas had transferred from Planning to the City Science and Technology Office. Therefore, a second planner had to be trained. It was decided by San Jose that the General Planning Division was a more appropriate organization to utilize Landsat than Zoning, so John Berg, the planner within General Planning responsible for maintaining the Department's land use inventory, was selected to attend the PSU-ORSER Remote Sensing Training Course.

As a result of Zouzoulas' work it was determined that Landsat might be more appropriate for mapping land use changes than land use inventories. The demonstration project objective was to determine if Landsat could be integrated into the Urban Service Area Annual Review.

As part of the implementation of the Urban Development Policies incorporated into the General Plan in 1975 is an Urban Service Area Annual Review. The purpose of the Urban Service Area Review is to monitor and update annual increments of development and land absorption. Through this analysis the amount

Figure 3.9 Landsat Land Cover Classification of East San Jose Study Area

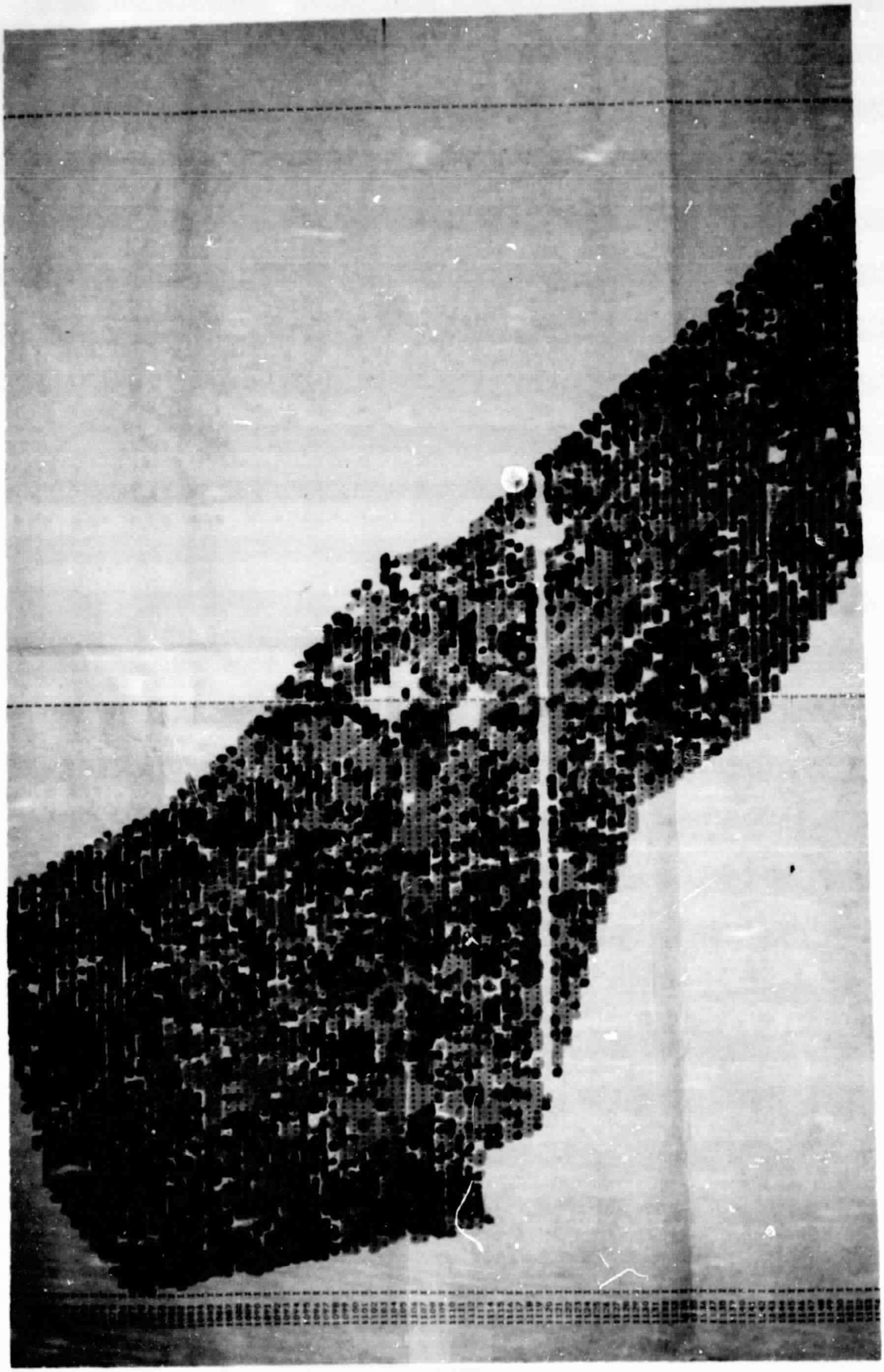


Figure 3.10 Landsat Land Cover Classification of Airport Vicinity Area Study

TABLE 3.12 Landsat Land Cover Area Measurements for San Jose Airport Vicinity Area Study

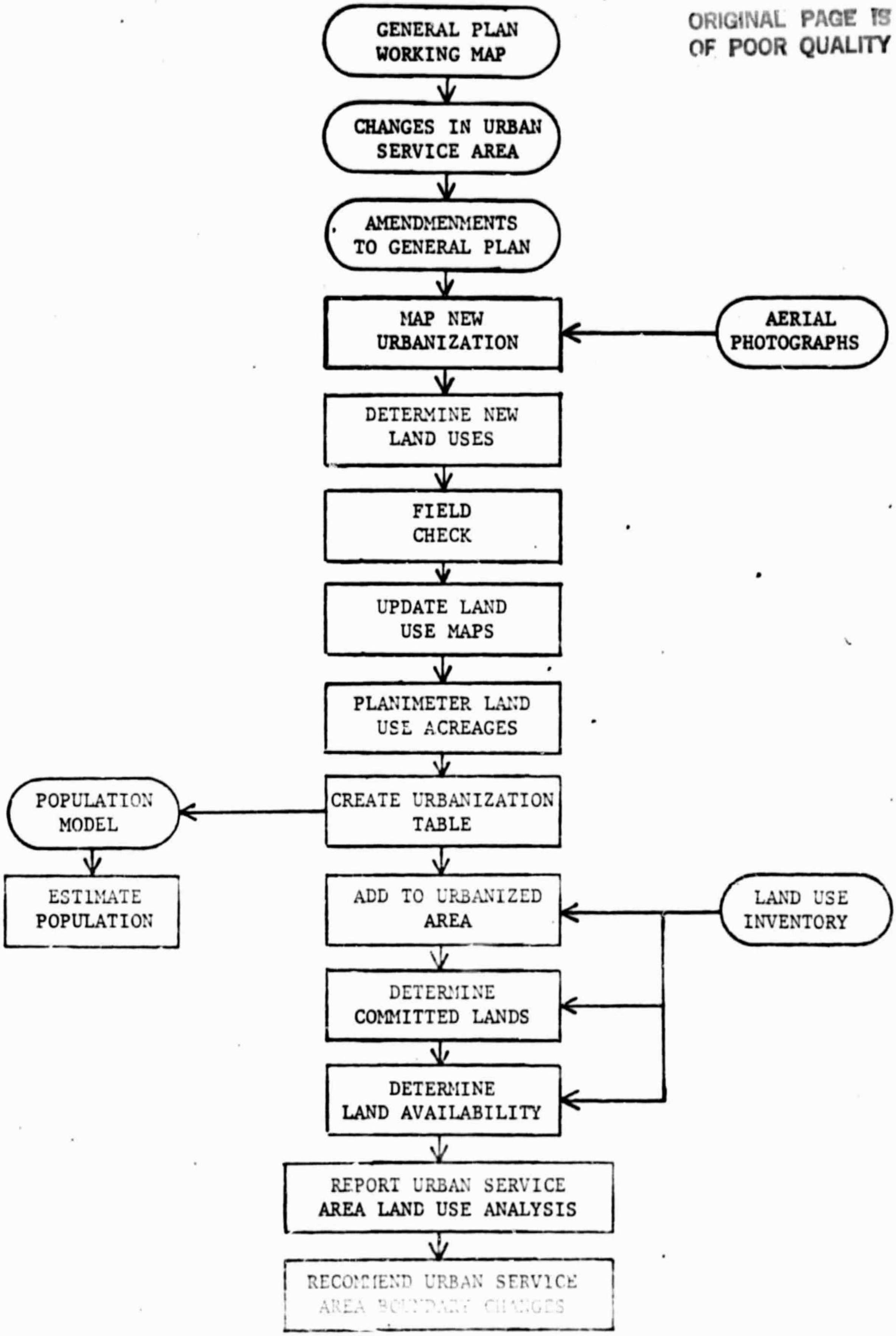
Land Cover	Acres	Percent
Residential	1,433	17.7
Building/Vegetation	744	9.2
Fields	2,409	29.8
Dark Earth	135	1.7
Pavement/Industry	637	7.8
Open Space/Irrigated Land	513	6.3
Orchard	575	7.1
Mobile Homes/Industry	272	3.4
Industry	1,000	12.4
Unclassified	368	4.5
TOTAL	8,086	100

and distribution of land available for development within the Urban Service Area can be analyzed and amendments to the Urban Service Area boundary reccommended. This analysis is conducted annually as part of the General Plan and Urban Development Policy review.

The two major components of the Urban Service Area Annual Review analysis are the vacant land inventory and the land availability analyses both reflecting conditions as of July 1 (Figure 3.11). A land use inventory was completed in 1974 as part of the General Plan and has been annually updated since then. Black and white 1:12,000 scale aerial photographs are obtained each April, from a commercial survey firm. Annual cost has been about $1,500 but went up to $2,400 in 1978. New urban development is identified and interpreted from the aerial photographs, and used to update an Urban Area Map and a Functional Land Use Map. The acreage of new urban development is manually measured using planimeters and dot grid screens. The acreage statistics are then used to determine the number of years of available land left in the Urban Service Area and as input to a population mode. Vacant and agricultural land are categorized according to present "commitments" of uses: vacant public committed, vacant private committed, vacant Williamson Act land, vacant industrial reserve lands, and vacant non-committed land. Finally, the data are tabulated by Planning Area, and recommendations are made for changing the Urban Service Area boundary. Between 1970 and 1977, 13,000 acres were urbanized and 3,000 acres was added to the Urban Service Area. Approximately 10 man-months of labor is required to conduct the analysis.

The intent of the Landsat demonstration was to determine if Landsat could (1) flag areas of new urban development particularly in areas where the City has not previously obtained aerial photographs and (2) identify the change in land use. The first several months of the project John Berg spent familiarizing

Figure 3.11 Urban Service Area Annual Review Process



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himself with the ORSER system. In April, 1978, work was begun on the change detection. The ORSER staff and ERRSAC were consulted about procedures for obtaining change detection using the ORSER system. No procedures were known, however, since apparently no one had ever done a change detection on the ORSER system. Four potential techniques were, therefore, suggested to San Jose: (1) map comparison of brightness maps; (2) classification of two merged Landsat images (8 multi-spectral channels); (3) classification of transformed merged Landsat images; and (4) histogram trimming of multidate ratioed images. All four techniques require precise registration of the Landsat picture elements from two images with each other, which requires precise geometric corrections of the Landsat images not available in the ORSER software. At the time ERRSAC did not have an operational and image processing system capable of registering two images, so it was decided to proceed using the ORSER system.

After several weeks, the San Jose planners succeeded in registering two images, however, with only the ORSER character map it was not possible to determine how good the registration was. A change detection map made by comparing (MAPCOMP) two normalized brightness maps (NMAP) was generated (Figure 3.12). The purple and blue areas increased in brightness and the red and orange areas decreased in brightness. The large contiguous areas correctly identified changes, however the several small, scattered pixels could not be related to known urban developments. Additional attempts to develop unique signatures for land use changes did not produce any concrete results.

One other achievement of the San Jose project was to experiment with the use of microcomputer technology as an intelligent terminal to the ORSER system. Instead of a keyboard terminal to the input and output from the ORSER computer, San Jose connected a second computer with its own printer, keyboard, and storage devices to the ORSER computer. The San Jose personnel wrote a program in BASIC

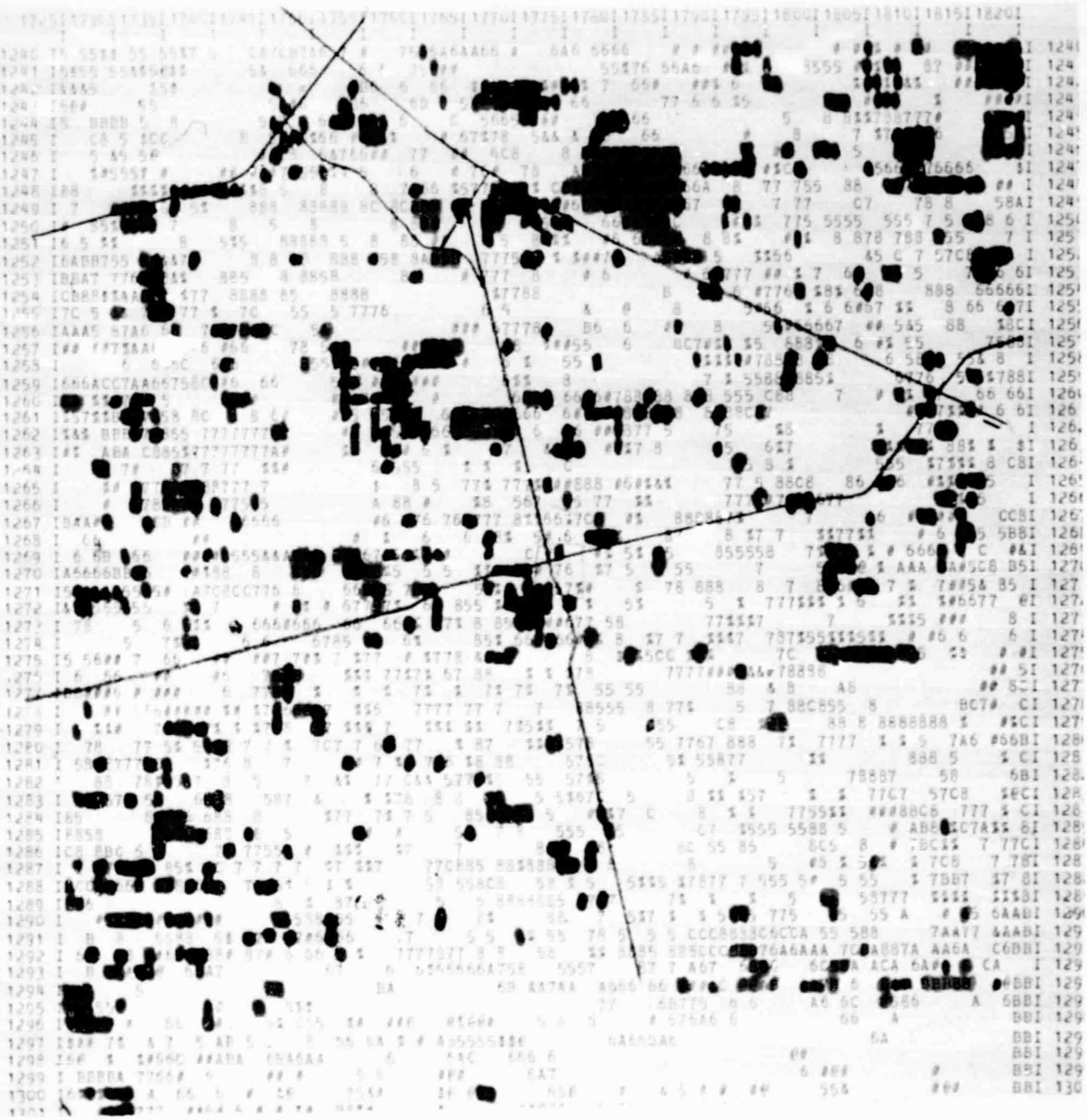

Figure 3.12 San Jose Landsat Change Detection Map Using ORSER System

language to enable the two computers to "talk". Potentially, the use of microcomputers as ORSER terminals could reduce data processing and data file storage charges by performing some processing "off-line" on the microcomputer. The San Jose personnel did not keep records to determine if in fact the microcomputer was more cost effective. They did find, however, that there was no cost advantage in storing data files on the microcomputer. To transmit a 500 line file at 300 band rate would take about 20 minutes and cost about 60 cents in computer connect charges and $6.00 in long distance telephone charges. The same file could be stored on the PSU computer for 1 cent per file day. Thus, unless faster communications were used or file storage charges were high, use of a remote microcomputer to store ORSER files would not be cost effective. The microcomputer did, however, enable the San Jose planners to perform additional manipulations on the ORSER data. For example, the planners used the microcomputer to display multispectral signatures graphically using an intelligent graphics terminal.

3.6 Summary of Local Experiences

Four of the initial five planning departments originally in the project developed internal capabilities to process Landsat data and conducted demonstration projects in an attempt to apply Landsat derived information to locally selected planning problems. Minneapolis, the smallest site in geographic area and the only site with a strong regional government with regional planning authority, dropped out of the project without initiating a demonstration project when a new administration took office and no potential applications could be identified.

In all of the jurisdictions the planning departments were selected to conduct the project. The planning departments function chiefly as advisory organizations to appointed planning commissions, the chief administrative officer, and elected legislative or boards. Departmental organization varied, but generally, each department was organized into 2 to 4 divisions and several sections. All of the planning departments (except Oklahoma City) had responsibilities for both zoning and subdivision regulation adminstration ("current planning") and policy or project planning ("advanced planning"). In Oklahoma City policy and project planning are handled by the Planning Department and zoning by another department. Generally the zoning divisions were larger than the policy or project planning divisions (Atlanta is the exception). Personnel shortages or cutbacks were a problem in all of the departments. Frequently, planning work program elements were reduced in order to accomplish the adminstrative work schedule and objectives with the available resources.

All of the departments have small research or information services sections to support the advanced planning divisions. These sections are generally responsible for maintaining planning data bases consisting of statistical information, property files, and maps, and for preparing data summaries, projections,

or forecasts. These research sections are not usually oriented to conduct original or experimental research.

Responsibility for the Landsat project was assigned to these research sections, except in Atlanta where the project was assigned to the then Assistant Zoning Administrator.

Each of the jurisdictions have recent comprehensive plans which are regularly updated in some fashion -- usually annually. The three cities' planning processes were all organized around neighborhood planning concepts at which level citizen input is greatest and specific program actions are recommended. Henrico County's planning process is not broken down into subareas although data are regularly reported by magisterial districts, traffic zones, watersheds, etc. Atlanta and Minneapolis did not have a recent city-wide inventory of existing land uses. Atlanta is currently developing an inventory on a neighborhood by neighborhood basis; Minneapolis' land use was last surveyed in 1953. Very large, time consuming efforts are required to develop these inventories; Minneapolis' and Oklahoma City's surveys both required three years to complete. The land use inventories are by functional land use category using modified versions of the HUD/BPR Starndard Land Use Code (Table 3.9). Only Henrico County and San Jose had procedures for regularly updating the land use inventories. Henrico uses permit applications and administrative records, and San Jose uses black and white aerial photography flown annually. None of the planning departments had automated geographic base information systems, although the Public Works Departments in Minneapolis and San Jose had or were acquiring systems. Atlanta and Minneapolis have computerized parcel information files, and Oklahoma City utilizes automated files from R.L. Polk Co. The San Jose Planning Department was the only department to have its own computer -- microcomputer used to store and produce management summaries of permit applications.

TABLE 3.13

LAND USE CATEGORIZATION SYSTEMS

OKLAHOMA CITY	SAN JOSE	HENRICO	ATLANTA	USGS-1976	USGS-1973	STANDARD LAND USE CODE
Residential						
Single Family 2-4 Family Multi-Family Mobile Homes	Single Family Multi-Family Mobile Homes	Single Family Multi-Family	Single Family Multi-Family	111 Single Fam. 112 Multi-Fam. 113 Group Qtrs. 114 Res. Hotels 115 Mobile Homes 116 Transient Lodgings 117 Other	11 Residential	11 Household Units 12 Group Quarters 13 Res. Hotels 14 Mobile Homes 15 Transient Lodgings 19 Other
Commercial						
Commercial Offices	Shopping Ctrs., Offices, Banks & Clinics Other Comm.	Comm. Svcs. Offices	Commercial	12 Commercial Services	12 Commercial Services 17 Strip & Clustered Settlement	51-59 Trade 61-69 Services
Industrial						
Industry	Manufacturing Non-Manufacturing	Lt. Industry Hvy. Industry	Industrial	13 Industrial 15 Industrial & Commercial Complexes	13 Industrial	21-29 Manufacturing 31-35 Manufacturing
Oil, Mining					14 Extractive	85 Mining
Transport., Commun. & Utilities				14 Transport., Commun. & Utilities	15 Transport., Commun. & Utilities	41-49 Trnasport., Commun. & Utilities
				16 Mixed Urban	18 Mixed	
Public & Semi-Public	Pub. & Quasi Pub. Struct.	Public Usage	Pub., Instit. & Open Space		16 Institutional	71-76 Cultural, Entertain., & Recreation
Park & Open Space	Pub. & Quasi Pub. Open Space	Semi-Public Usage		17 Other Urban	19 Open & Other	
Agriculture	Agriculture	Prime Vacant Conservation		21-24 Agriculture	21-24 Agriculture	81-82 Agriculture
				31-33 Rangeland	31-34 Rangeland	83 Forestry
Vacant	Vacant	Vacant	Undeveloped	41-43 Forest	41-43 Forest	84 Fishery
Railroads	Railroads			51-54 Water	51-55 Water	91-95 Undeveloped Land & Water
Maj. Streets & Highways	Loc. Streets Freeways	Roads		61-62 Wetland	61-62 Wetland	
				71-77 Barren	71-75 Barren	
				81-85 Tundra	81 Tundra	
				91-92 Snow & Ice	91 Snow & Ice	

Generally, one planner in each city was assigned to work on the Landsat project part-time -- usually 4-12 hours per week. In Oklahoma City a two-person project team approach was utilized - a senior planner and an administrative aide plus some University personnel. After giving the project initial approval, management level of involvement consisted mostly of periodic reviews of the project progress. The chief executive officers or elected officials were not involved in the projects except to initially approve participating in the program. The UTS Technology Agents did not become technically involved in assisting the projects. However, their role was very important in introducing the technology to the cities, obtaining initial commitments of the planning departments to participate, and in politically supporting the projects as they progressed.

The project participants' utilization of the ORSER processing system is summarized in Table 3.10. On average, each site utilized under 200 hours of computer connect time, or about 15 hours a month. Three of the participants averaged about 130 minutes of computer processing time; San Jose used 300 minutes. Computer costs averaged \$1,000 for three of the sites; San Jose utilized \$2,400 worth of computer charges. In addition to computer charges, the national WATS telephone line established for the cities to connect with the PSU Computation Center cost an average of \$1,000 per month, or 12 times the average computer charges. In addition to NASA's costs for the PSU computer and telephone line charges, each of the cities committed about 12 man weeks of labor and an average \$1,500 each for the computer terminals.

Each of the cities were able to produce general land cover maps from their application demonstration projects, but these maps only partially fulfilled the original objectives of the cities' projects. The land cover categories derived by the local governments using Landsat are shown in Table 3.11. Generally these

TABLE 3.14 ORSER SYSTEM UTILIZATION BY LOCAL GOVERNMENTS LANDSAT APPLICATIONS PROJECT, NOVEMBER, 1978 THROUGH DECEMBER, 1978

ORSER SYSTEM UTILIZATION PERIOD: 11/1/77 TO 12/31/78

	CONNECTIONS **			CPU **			STORAGE **		OUTPUT **	TOTAL COST **		PERFORMANCE ***		
	NO	HRS	COST	JOBS	MIN	COST	FL-DA	COST	LINES			JOBS / CONNECT	CPU / CONNECT TIME	CPU COST / TOTAL COST
[illegible]	218 15.6	183.36 13.1	341.46 24.39	605 43.2	134.73 9.6	577.50 41.20	5,029 359.2	61.94 4.42	60,835 4,345	980.90 70.06		2.78 .57-5.00	1.22 .36-3.17	.59 .23-.81
[illegible]	354 25.3	194.87 13.9	313.11 22.37	510 36.4	153.45 10.9	670.92 47.92	12,175 869.6	148.64 10.62	90,138 6,348	1132.67 80.91		1.44 .06-6.66	1.31 .21-3.61	.59 .27-.81
[illegible]LIS *	29 -	16.80 -	20.16 -	48 -	11.95 -	57.36 -	262 -	5.24 -	11,039 -	82.76 -		1.66 -	1.19 -	.69 -
[illegible] CITY	212 15.1	187.27 13.4	326.59 23.33	407 29.1	112.67 8.1	484.72 34.62	8,895 635.3	96.01 6.86	64,227 4,587	907.44 64.82		1.92 .63-4.00	1.00 .27-3.57	.53 .32-.78
[illegible]	364 26.0	307.30 21.9	527.89 37.71	1604 114.6	300.82 21.5	1319.12 94.22	37,251 2661.5	574.75 41.05	130,325 9,308	2421.76 172.98		4.41 .66-6.44	1.63 .15-3.57	.54 .04-.78
[illegible]	114 8.1	57.60 4.1	92.39 6.60	153 10.9	27.25 1.9	117.40 8.39	3,786 270.4	60.66 4.33	30,083 92,148	270.39 19.31		1.34 .27-7.50	.79 .30-5.24	.43 .20-.64
[illegible]	1,291 92.2	947.20 67.7	1,621.60 115.83	3327 237.6	740.87 52.9	3227.03 230.50	67,408 4814.8	947.18 67.66	386,547 27,617	5795.92 413.99		2.58 -	1.30 -	.56 -

* Minneapolis dropped out of program after training short course

** Total
14 Month Average

*** Monthly Average
Minimum-Maximum

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categories compare in detail with the Level I Land Cover Classification Scheme proposed by the U.S.G.S. Compared with the functional land use categories presently used by the cities (shown in Table 3.9), the Landsat land cover categories provide much less detail in the built-up classes (residential, commercial, and industrial categories) and more detail in the undeveloped or vacant areas (agriculture, forest, grassland, wetland, water).

Two sites, Oklahoma City and San Jose attempted to demonstrate the use of Landsat for monitoring urban change. Oklahoma City used the approach of independently classifying landcover types in two images using an unsupervised cluster algorithm and comparing the two resulting maps. This approach suffers, however, from inconsistencies and errors which exist in each of the maps when prepared this way. San Jose attempted to combine two Landsat images into a single composite image to identify unique spectral signatures of changed areas. This approach has been used by other Landsat investigators.[1,2] However, it was found that the ORSER processing programs did not have the necessary capabilites to successfully register, normalize, and difference multi-date Landsat images.

Despite the technical problems and limitations experienced by the four sites, the overall impact of the program was positive.. All of the participants indicated that they had developed a much greater understanding of all types of remote sensing and of computer data processing techniques as a result of the program. This impact generally went beyond those individuals directly involved in the projects to other members of the planning departments, and in some cases other departments. The projects, in particular, highlighted the need for greater data coordination and development of automated data bases in most of the sites. In addition to providing valuable insights into the needs,

TABLE 3.15

LANDSAT LAND COVER CATEGORIES PRODUCED BY LOCAL GOVERNMENTS

	OKLAHOMA CITY	OKLAHOMA CITY	SAN JOSE	HENRICO	ATLANTA
Processing System:	ORSER	ERDAS	ORSER	ORSER	ORSER
Landsat Id:	2864-16085	2864-16085	1705-18100	2904-14461	2782-15164
Image Date:	June 4, 1977	June 4, 1977	June 28, 1974	July 14, 1977	March 14, 1977
	Residential	Residential	Residential Mobile Homes/ Freeways	Residential	Residential High Density Residential
	Commercial/ Industrial	Commercial/ Industrial Asphalt	Commercial/ Industrial Pavement/ Parking Lots	Commercial/ Industrial	Commercial/ Industrial
	Agriculture Prairie	Agriculture	Agriculture Rangeland	Agriculture	Open Space/ Public
			Irrigated Open Space Riparian Habitat/ Trees	Hardwood Forest Softwood Forest	
	Bare Ground/ Fallow Fields Wetlands	Bare Ground/ Fallow Fields Wetlands	Bare Ground/ Excavation	Mined Areas	Undeveloped
	Water	Water	Water	Water	Water

issues, and potential for transferring Landsat technology to local governments, the results of the applications projects demonstrated that satellite remote sensing may require 2-3 years of further research and modification before it is ready for wide adoption and transfer to local governments.

References

1. Gary Angelici, Nevin Bryant, Steven Friedman, "Technique for Land Use Change Detection Using Landsat Imagery," Jet Propulsion Laboratory, Pasadena, California, no date.

2. Mark Stauffer and Richard McKinney, Landsat Image Differencing as an Automated Land Change Detection Technique, Interim Report, Contract NAS5 - 24350, NASA Goddard Space Flight Center, Greenbelt, Maryland, August, 1978.

4.0 OKLAHOMA CITY CASE STUDY

4.1 History of Oklahoma City

Oklahoma City's inception occurred in one day with the "land rush" in 1889, when the Unassigned Lands in Central Oklahoma were opened for settlement by non-Indians. At noon on April 22, 1889, settlers were lined-up along the boundary of the Unassigned Lands, and at the prearranged signal of a gun shot 'ran' on foot, bicycle, horse, buggy, and wagon to claim their homesteads. Each male adult U.S. citizen was entitled to claim one quarter-section (160 acres) of farm land or 6 town lots in one of the several previously designated town sites. By nightfall approximately 6,000 people were camped along the banks of the North Canadian River at the site of the Oklahoma Station of the Santa Fe Railroad.

Oklahoma City grew rapidly as a trade and agricultural center. By 1900, the population had reached 10,000. In 1910, three years after statehood, the state capital was moved from Guthrie to Oklahoma City. The local economy expanded rapidly and the population increased to 91,295 in 1920. The discovery of oil during the 1920's changed the economy and brought more growth. The population doubled in size in ten years reaching 185,000 persons by 1930. Economic depression and drought slowed the city's growth during the 1930's. World War II and the many plant workers required by the war effort revived the local economy, but it was not until after the war that another boom occurred.

Following the close of World War II, the increased availability of the automobile permitted new housing to be constructed in areas apart from those served by the traditional streetcar lines. To provided services to this new growth the city began a program of annexation. Between 1940 and 1960 the city's incorporated area increased tenfold from 26 square miles to 266 square miles; and in the ten years between 1960 and 1970, it tripled again to almost 649

square miles. These annexations resulted in the city gaining jurisdiction over three of the region's important water reservoirs, as well as much of its potentially developable land.

4.2 Environment

Today Oklahoma City is 621.4 square miles in size, the second largest municipal area in the United States. OKC is characterized by a large urbanizing fringe and large undeveloped areas within the city limits. Only about 25 percent of the city is developed; 75 percent of the land area is vacant or used for agriculture. Oklahoma City is located in three physiographic regions: wooded sandstone uplands known as the "Cross Timbers"; The "Reddish Prairie" underlain by shale and soft sandstone; and the "Bottonlands" consisting of the alluival floodplains along the Canadian and North Canadian Rivers.

Oklahoma City's climate is semi-arid; average rainfall is 30 inches per year and is unevenly distributed throughout the year. Extreme drought conditions alternating with flood conditions are the result. The dissipation of storm water is a major development problem. Most OKC soils are relatively unstable and highly susceptible to erosion from both wind and water when the native groundcover is disturbed. The use of septic tanks is unsuitable in most of the community due to soil characteristics and the presence of bedrock.

4.3 Form of Government

Oklahoma City has a Council-City Manager form of government. One council representative is elected from each of eight wards. The Mayor, who acts as City Council Chairman, is elected at-large. City Council members, including the Mayor, serve 4-year terms and may succeed themselves any number of times

The City Council's responsibilities are legislative only. The City Manager is responsible directly to the City Council, and is the Chief Administrator for the city.

Major functions of the City are divided among ten departments. Depending on the size and scope of activity, the departments are further divided into divisions and sections.

4.4 Fiscal Resources

General obligation bonds are issued by the city of Oklahoma City to raise revenue for large scale capital improvements. These bonds are repaid out of ad valorem property taxes collected by the four counties operating within OKC city limits. Property assessment rates and tax revenue allocations are set by the County Excise Boards rather than the city government. Federal and state grants are used for specified types of approved municipal improvements (largely roads, parks and urban renewal). In Oklahoma revenue bonds can only be issued by trusts and special authorities to finance improvements such as water treatment and distribution systems, airports, refuse collection equipment, and recreational facilities whose debt can be retired through service charges or entrance fees.

The cities general revenue fund for operating and maintenance functions is derived from a 1% sales tax; utility franchise taxes; water, sewer, and garbage, service fees; and federal general revenue sharing and CETA funds. General revenue sharing accounts for 12% of the city operating budget. Less than 1% of the city's revenues come from ad valorem taxes. State funds amount to less than 4% of the operating revenues and are used mostly for street maintenance.

School districts are entirely dependent on local property taxes to finance capital improvements. Revenues for school operations come from three sources -- ad valorem taxes, state aid, and special federal programs. Over 70% of the property tax collections are spent to support schools.

4.5 Land Use Planning History

In the face of the almost frantic growth Oklahoma City was experiencing in the 1920's, a Planning Commission was organized in 1923 pursuant to new state enabling legislation. Also in 1923 a zoning ordinance was prepared, approved by the Planning Commission, and adopted by the City Council.

In 1931, a city plan for Oklahoma City, prepared by a consulting firm, was published.[1/] The plan recommended a coordinated street improvement program, a Civic Center, a system of neighborhood and regional parks, and a new zoning ordinance. The only proposal made in the 1931 Plan that was substantially implemented during the depression years was the construction of a downtown Civic Center.

By 1944, public officials, anticipating the pressure of growth after the end of the war, hired a planning consultant firm to develop a new comprehensive plan. The plan was published by the Oklahoma City Planning Commission in 1949.[2/]

The 1949 Plan was predicated on the assumption that predictable economic growth and development would form the basis for planning in Oklahoma City. The plan called for the gradual extension of city limits and containment of population within a distance of five miles from the central business district (CBD), in order to prevent the city from outrunning its capacity to provide necessary facilities and services.

In 1975, responding to impending fiscal crises, Oklahoma City undertook a two year program to prepare a third comprehensive plan. Oklahoma City's

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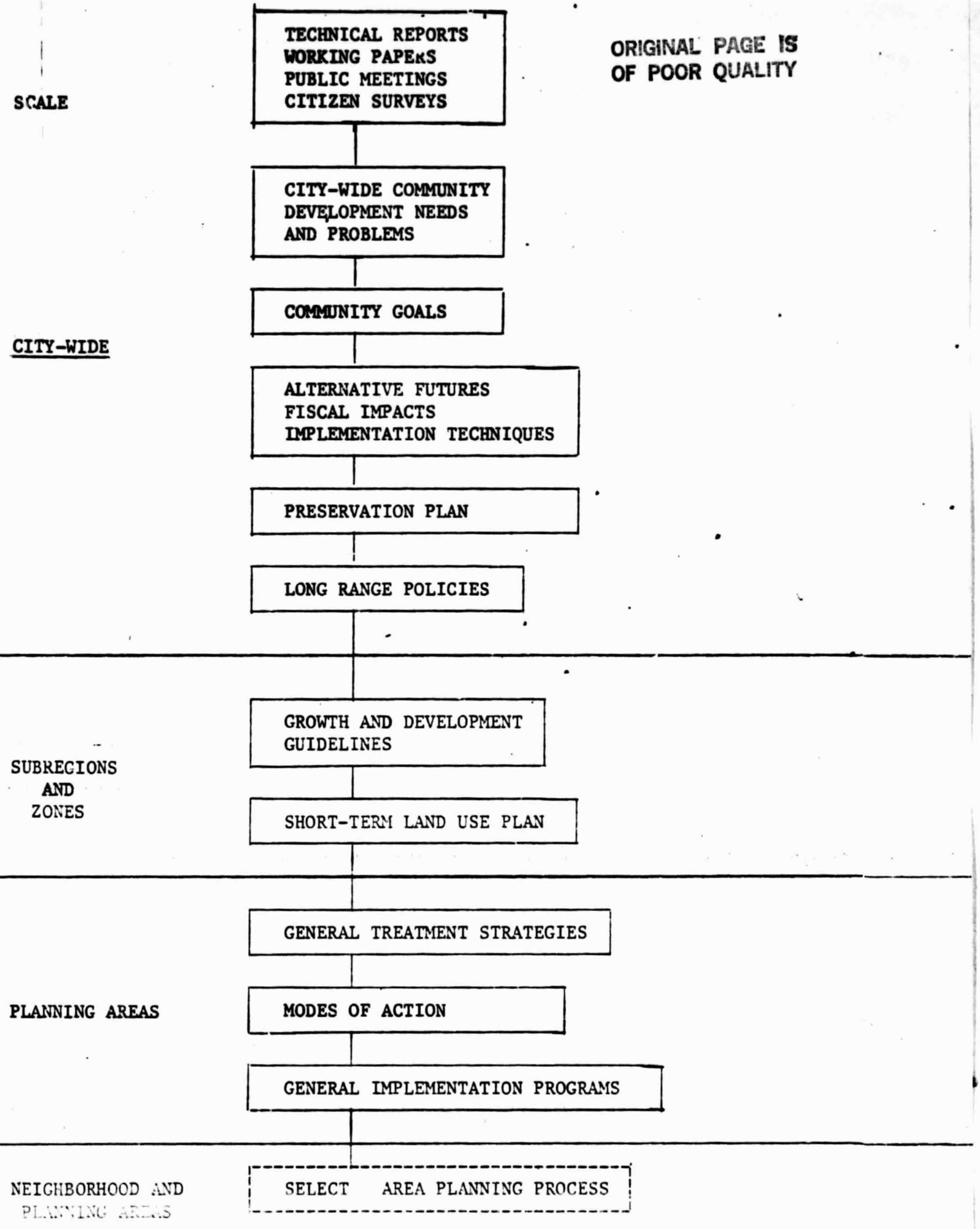

Figure 4.1 Oklahoma City Comprehensive Plan for Growth Management and Community Development Process

outstanding debt had increased to 25% of its assessed valuation; debt repayment accounted for nearly 30% of the city's fiscal resources. A consultant's report concluded that if current trends continued the city's severely constrained ability to raise revenues to provide capital improvements and services to new development would bankrupt Oklahoma City.[3/]

The Planning Commission published Oklahoma City's Comprehensive Plan for Growth Management and Community Development in 1977.[4/] The plan consists of two primary documents: the Preservation Policy Plan which focuses on goals and policies to guide growth to the year 2000, and the Preservation Action Program that defines the steps to implement the Policy Plan during the first ten years. In addition, 29 technical reports were produced to provide background data, analyses, and guidelines to support the final plan. These reports include analyses of existing conditions and problems, growth forecasts, alternative plan and evaluations, financial analyses, and implementation programs and procedures.

The 1977 OKC Plan projects that between 1975 and 2000 Oklahoma City's population will increase 44% from 391,600 to more than 564,000. Oklahoma City is expected to continue to capture about half of the population in the three county metropolitan area. By 2000, metropolitan employment is forecast to total 305,200, an increase of 61% over 1975. Demand for new housing between 1977 and 2000 is estimated to be 166,900 units - 196% increase over the existing 157,000 units. This translates into an average annual production of over 7,250 dwelling units.

The two key goals of the 1977 OKC Plan are:

1. Encourage efficient and cost-affective growth patterns in regard to land, energy conservation, and fiscal resources; and

2. **Preserve and revitalize existing neighborhoods and business areas to arrest neighborhood decline and protect existing housing, private and public investments.**

Improved public maintenance, correction of service deficiencies, and public assistance for housing rehabilitation are stressed in existing neighborhoods. New growth is to be directed to be more geographically balance, located to reduce service costs, located on vacant land served by existing utilities, and located out of environmentally sensitive areas. Commercial and industrial growth is to be located in the downtown or in existing activities. Transportation policies are to shift toward greater utilization of public transit.

The Policy Plan targets 27,200 existing dwelling units for rehabilitation, 22,400 new inner-city units and 139,700 new suburban units by the year 2000. A total of 60 square miles of suburban development are estimated to be required by the Plan. By contrast, current trends if continued would require 84 square miles of suburban land, an increase of 40% above the Preservation Plan requirements. By reducing the land area of new development and conserving existing housing stock, the Preservation Plan is estimated to save over $250 million in capital improvement costs compared to the current trend projections.

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4.6 Select Area Planning Process

The OKC Plan sets out long-range, city-wide goals and policies, and identifies short-range implementation strategies and actions for each of the city's planning areas. The job of implementing and detailing the OKC Plan at the neighborhood and program level was left to the Select Area Plan Process. Through the Select Area Plan Process needs are identified and priorities established for community and neighborhood improvement of each of the city's 45 planning areas. Neighborhood groups present problems, needs, and goals at city-sponsored neighborhood workshops. The city staff provide background data; research; urban design, physical and social planning expertise to translate these identified goals and needs into specific design solutions, capital improvements, zoning concepts, economic programs, and housing programs. The Select Area Plan consists of two reports:

1. The Resource Document -- prepared by the Planning Department's Data Monitoring and Research Section is a background report on the planning area. It contains an inventory of demographic, land use, zoning, housing, business and industry, and urban services and facilities data summarized into findings and yielding major issues and problems.

2. The Strategy Document -- prepared by the Urban Design Division of the Planning Department and citizens' groups deals with recommended city for the planning area. The document is concerned with six major areas: Land Use, Zoning, Capital and Services Improvements, Community and Social Opportunities, Economic Opportunities, and Future Urban Structure.

The Data Monitoring and Research Section's primary products include:

Population data - derived from 1975 U.S. Census, R.L. Polk Profiles of Change, National Planning Data Corp. estimates, NTIS, and Oklahoma Employment Securities Commission

Economic data - same sources as above

Housing data - 1979 U.S. Census, aerial photography, building permits, R.L. Polk

Aerial photos - 1976 reproducible cronars and 1978 black and white prints at 1" = 880' scale

Maps - 1968 planimetric maps (1" = 200' scale), zoning maps (1" = 400'), census tracts (1" = 6,000' and 1" = 12,000'), base maps (1" = 12,000').

A primary source of OKC's Planning Department's data base comes from the R.L. Polk Profiles in Change service.[5/] Begun in major U.S. cities in 1974 under a U.S. Department of Housing and Urban Development grant, the R.L. Polk provides an annual canvas of households. The city purchases this information annually for approximately $30,000. The R. L. Polk reports and computer files contain five records: (1) structure (housing supply), (2) household (demographics), (3) commercial enterprises, (4) occupation and income, and (5) neighborhood status and change. The OKC Planning Department has developed ADMATCH programs to pull out the R.L. Polk data by geographic areas, but has not automated mapping or graphics capabilities. The R. L. Polk data are used in updating population and housing data, preparing resources documentation for the Selected Area Planning Process, supporting housing conservation and rehabilitation programs, and in preparing the 1977 Land Use Inventory.

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Table 4.2 Maps Maintained by Oklahoma City Planning Department

- Activity Centers
- Base Maps (1" = 12,000')
- Census Tracts (1" = 6,000', 1" = 12,000')
- Fire Protection
- Flooding Maps
- Housing Characteristics
- Land Use (1" = 400')
- Neighborhood Organizations
- Parks and Recreation
- Planemetric Maps (1" = 400')
- Planning Areas
- Plan Maps (1" = 6,000')
- Short Term Land Use Plan
- State Highways
- Streets
- Subdivisions
- Topographic (1:24,000)
- Urban Services
- Zoning (1" = 400')

4.8.1 Land Use Inventory Techniques

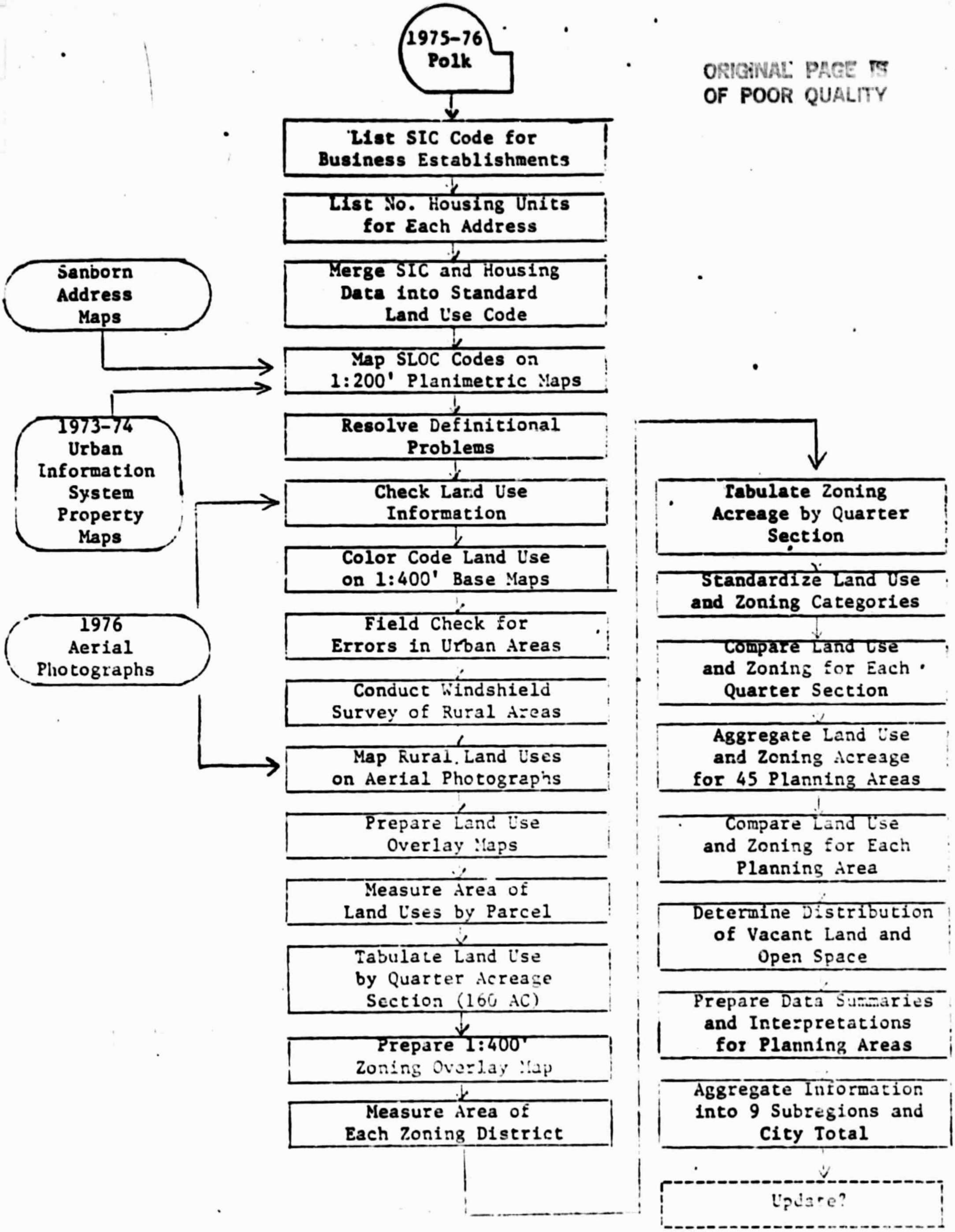
In 1979 the Data Monitoring and Research Section completed a three year project to prepare the first complete city-wide inventory of existing land uses in OKC since the 1949 Comprehensive City Plan. During that thirty year period the city had grown in land area from 26.33 square miles to 621.49 square miles, and in population from 226,000 to 391,000. The main sources of information used in the inventory were:

- 1975-76 R.L. Polk data by address
- Planimetric maps at 1" = 200' scale (prepared from 1968 aerial photographs)
- Sanborn Address Maps
- 1973-74 Urban Information System Property Maps
- 1977 Base Maps at 1" = 400' scale
- 1976 Aerial Photographs at 1' = 400' scale
- 1977 Field Survey

The inventory was prepared in nine major steps:

1. Convert the Standard Industrial Classification (SIC) land use information and housing information from the R.L. Polk files to a modified Standard Land Use Code (SLUC), and map land use information for central urbanized area on 1" = 200' planimetric maps.
2. Color code land use information on 1" = 400' base maps, field check urban areas for errors, and map rural area land uses from aerial photographs and windshield surveys.
3. Prepare land use overlay maps and tabulate acreages of land uses by quarter sections.
4. Prepare zoning overlay map and tabulate acreage of zoning categories by quarter sections.
5. Compare land use and zoning acreages for each quarter section.
6. Compare land use and zoning acreages for each section.

Figure 4.2 OKLAHOMA CITY 1976-79 LAND USE INVENTORY PROCESS



7. Compare land use and zoning acreages for each of 45 planning areas and determine distribution of vacant, park, open space and public land by zoning categories.
8. Prepare data summaries and interpretations for 45 planning areas.
9. Aggregate land use and zoning information in to 9 subregions and city total.

Approximately twenty man-years of effort were required to complete the inventory and land use profiles. Primary products of the inventory include:

- 76 color coded parcel-level land use maps at 1" = 400' scale (non-reproducible)
- Land use acreages by parcel, quarter section, section planning area, subregion and city total
- Zoning category acreage by zoning district, quarter section, section planning area, subregion and city total
- Land use and zoning comparisons by quarter section, section and planning area
- Land Use Profile Report

The data is current to January, 1977. At present there is no mechanism for producing reproducible land use maps or updating the land use information.

Table 4.3 ACREAGE OF OKLAHOMA CITY 1977 LAND USES

	Acreage	% of Developed Acreage	% of Total Acreage	Acreage Zoned
Residential				
Single Family	32,732	32	8	
2-4 Family	1,237	1	*	
Multi-Family	1,944	2	*	
Mobile Home	546	*	*	
Total Residential	36,459	35	9	120,504
Commercial				
Commercial	5,990	6	2	5,989
Office	549	*	*	979
Industrial				
Industry	3,365	3	1	
Oil, Mining	889	1	*	
Transportation, Communication, and Utilities	3,420	3	1	
Total Industrial	7,674	7	2	25,790
Agriculture	1,656	2	*	193,429
Public & Semi-Public	3,834	4	1	(3,834)
Park and Open Space	18,146	18	5	(18,146)
Vacant	294,362	--	74	
Railroads	1,319	1	*	(1,319)
Major Streets & Highways	15,375	15	4	(15,375)
Special Governmental Uses	12,335	12	3	(12,335)
TOTAL ACREAGE	397,700	100	100	397,700

*less than .5%

4.9 Landsat Applications Project

Oklahoma City was not one of the five Urban Technology System (UTS) sites which participated in the PTI/NASA Remote Sensing User Requirements Committee (NASA Contract NAS5-22412). Oklahoma City replaced Independence, Missouri which dropped out of the URC when follow-on project proposal negotiations became protracted. The proposal to participate in the Landsat Applications Project was introduced and sponsored locally by James Carter, UTS Technology Agent, then Assistant City Manager, and a physicist with previous infrared sensing and signal processing experience.

Project participation was approved by Norman Standefer, then Planning Director, and incorporated into the City Planning Department's work program for the 1977-78 fiscal year. The overall objective of the project for the Department was to explore the potential of Landsat and related technologies for improved urban analytical/research capabilities. Roy Reynolds, Senior Planner in charge of the Data Monitoring and Research Section was selected to oversee the project. At the time Reynolds had five years of city planning experience, degrees in architecture and city planning, and was a member of the American Institute of Certified Planners (AICP) and the World Future Society.

The OKC Landsat Project went through four identifiable phases:

1. Capacity Building Phase from the time of the Penn State Training courses in November, 1977 to the first Project Review Meeting in March, 1978.
2. ORSER Project Phase from March through June, 1978.
3. Earth Resources Laboratory Phase from June, 1978 through September, 1978.

4. <u>Conclusion Phase</u> from August through December, 1978.

4.9.1 Capacity Building Phase

During the Capacity Building Phase staff of the OKC Planning Department became familiar with the basics of the Landsat system; personnel were trained to operate the ORSER system and conduct the Landsat analysis; necessary equipment and ancillary data were obtained; demonstration project objectives established; and a cooperative network initiated of potential remote sensing users in the OKC region.

During the first two weeks of November, 1977, Reynolds attended the Remote Sensing Training Course given the project participants by the Office of Remote Sensing for Environmental Resources (ORSER) at Pennsylvania State University. A week after returning from PSU, a meeting was called to begin building a cooperative network of local remote sensing users, and establish objectives and directions for City Planning Department's Landsat demonstration project(s). In attendance at this meeting were:

Al Conradi -	District Conservationist, Soil Conservation Service;
Keith Vaughn-	Area Coordinator, 208 Program, State Conservation Commission;
Dr. Charles Barb-	Associate Professor. University of Oklahoma;
James Carter-	Technology Agent, Assistant City Manager, Oklahoma City;
Norman Standefer-	Planning Director, Oklahoma City;
Roy Reynolds-	Senior Planner, Oklahoma City, in charge of Landsat investigation;

and other senior planners in the OKC Planning Department. Two demonstration projects were selected on the basis of the Planning Departments needs and

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interests, and Reynold's report from the PSU Training Course. The two projects were:

1. Urban Growth Monitoring - Separate urban from agricultural land uses within the city's limits and determine the loss of agricultural acreage between two points in time.
2. Watershed Monitoring - Monitor land use changes in the Atoka Reservoir Watershed and relate changes in land use to changes in water quality. The Atoka Reservoir, one of the sources of OKC's water supply is located 80 miles from the city.

As the Landsat project progressed, the group represented at that first meeting continued to help in many ways. From the Soil Conservation Service came ground truth information on crops. Through the State Conservation Commission contact was made with James Dawson of the Oklahoma Research Foundation who was setting-up an image processing facility under contract to the State. The greatest interaction, however, was with Dr. Charles Barb of the University of Oklahoma Geography and Engineering Departments. As a back-up site for the City in the NSF Urban Technology System experiment, the University had cooperated with the City on 22 technology adoption projects; thus a strong working relationship existed between the City and Dr. Barb before the start of the Landsat Project. Dr. Barb, an urban geographer/planner who was instrumental in establishing the Urban and Regional Information Systems Association (URISA), had a grant from the Regional Applications Program at NASA's Earth Resources Laboratory (ERL) in Slidell, Louisiana, to develop curriculum material and conduct remote sensing courses at the University. Thus, the sharing of knowledge and experiences between the City's Landsat Project and Dr. Barb resulted in mutual benefits. Through Dr. Barb's grant with NASA/ERL, the OKC planners were able to attend a two-week short course at ERL and process their imagery on the ERL/ERDAS system; and through the City's

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project, Dr. Barb obtained case study materials and assistance in developing a remote sensing curriculum. The net effect of all of the organizational linkages among these groups, all of whom were at the time in stages of considering, experimenting, or developing remote sensing capabilities, was not so much technical assistance, but rather a broadening of the support base (coalition building) of a local "mass" of users.

By mid-December the remote computer terminal for operating the ORSER system program, a DECwriter II, was delivered and installed in the Planning Department's offices. Two other members of the Data Monitoring and Research Section were assigned to work on the project: Rick Banister, a computer programmer who was responsible for developing the section's R.L. Polk data base system; and Gerald Johnson, an Administrative Aide. Initial efforts concentrated on identifying sources of ground truth information.

In January, training of Bannister and Johnson on the ORSER programs was begun by Reynolds. The Landsat image being used was a June 4, 1977 scene (ID #2864-16085) with 10 percent estimated cloud cover which had been selected by NASA Regional Applications Program personnel prior to the PSU Training Course. Problems were encourtered with printing BAT files over 500 records long, so during the first week of February, PTI Project Coordinator Ned Buchman and Beldon Bly from the Computer Science Corporation's (SCS) contract support group at the Goddard Regional Applications Center were called in to provide on-site assistance and training. Three days assistance were required, during which Bly and Buchman demonstrated procedures for editing ORSER Job Control Language (JCL) statements to link BAT files, made recommendations on the procedures for utilizing ground truth and excillary data, and taught the OKC staff techniques for analyzing multispectral signatures from the ORSER STATS (statistical training) and CLUS (cluster analysis) programs. Following the technical assistance from

Bly and Buchman, work proceeded with statistical training (STATS) and uniform mapping (UMAP) of selected study areas.

In March, a Landsat image browse facility was located at the National Severe Storms Laboratory in Norman, Oklahoma. This depository contained uncataloged Landsat images on 70 mm film spools for August, 1972 through November, 1975. From these film chips a list of cloud-free, high quality images was made for use in ordering additional Landsat images.

March 15th and 16th, Reynolds, Johnson and Barb attended a Remote Sensing Applications in Resource Management Symposium at Oklahoma State University. Two direct impacts of attending the symposium were to broaden the City's approach to Landsat applications to include other available remote sensing sources in combination with Landsat, and to expand efforts to obtain different types and sources of ground truth information.

By the First Project Review Meeting, March 29-30, 1978, Oklahoma City had concluded the Capabity Building Phase and was transitioning into the ORSER Analysis Phase. The project was fully staffed, trained and equipped, demonstration objectives set, organization linkages established with other local groups interested in remote sensing, and ground truth data collection initiated. Several preliminary land cover signatures were developed and presented at the March Project Review Meeting.

4.9.2 ORSER Analysis Phase

Between April and the end of July, the bulk of the OKC Landsat Applications Project was devoted to analysis of two test sites utilizing the ORSER analysis system. The two test sites were the Bethany-Warr Acres area between Lake Hefner and Lake Overholser and the area around Tinker Air Force Base, and Lake Stanley Draper. The procedure developed for extracting multispectral signatures and

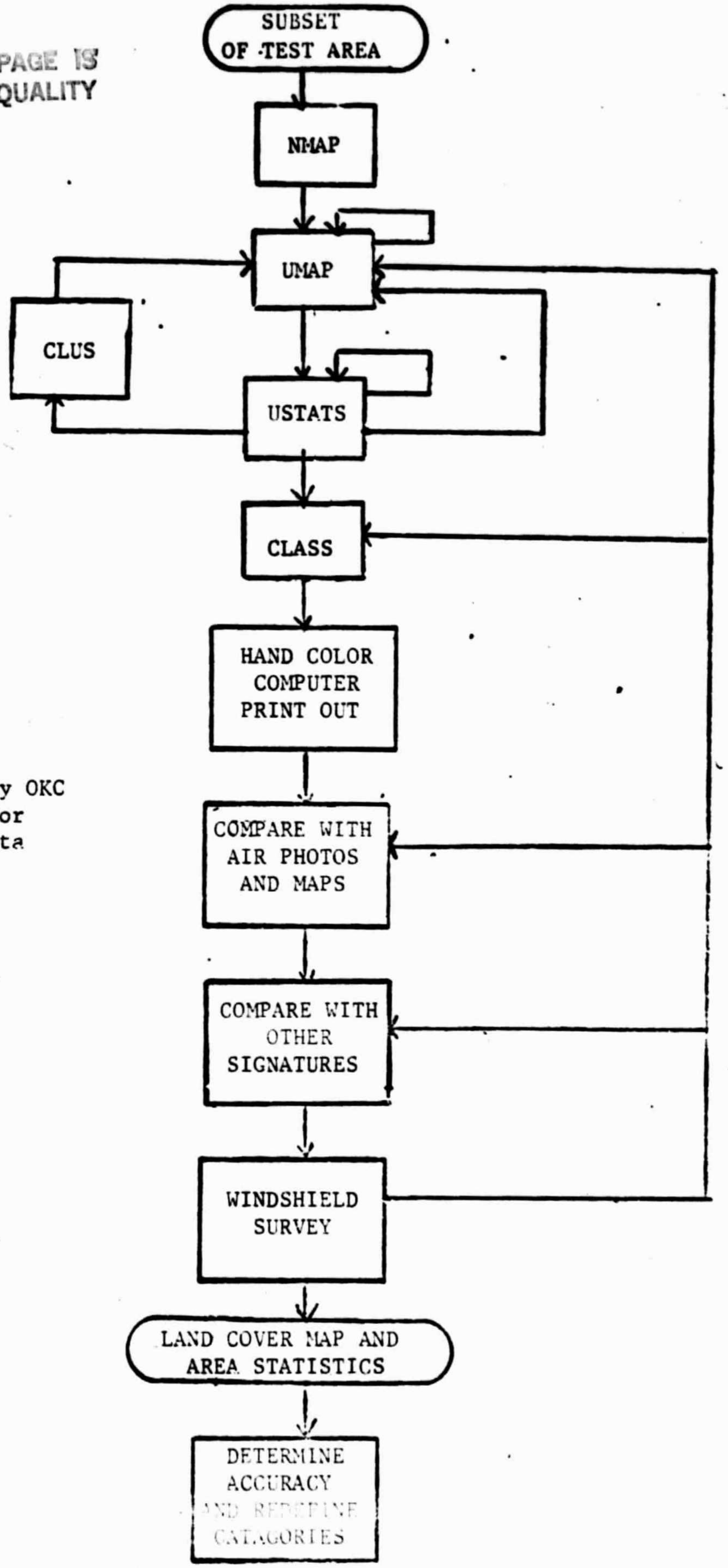

Figure 4.3
Procedure developed by OKC Planning Department for processing Landsat Data using ORSER system

classifying land covers was to iteratively identify large spectrally uniform areas (UMAP) and statistically train on the uniform areas (USTATS), or to perform a cluster analysis (CLUS) to indicate general areas for statistical training. After several spectral signatures were developed, one or several classification maps would be prepared by altering the signature parameters (bandwidth, bandwidth mean, and critical limit). The results were compared with aerial photos, existing maps, windshield surveys, and other ground truth data to identify areas or categories requiring additional statistical signature training.

Figures 4.4 and 4.5 show the land cover classification results obtained after four months for the Bethany-Warr Acres and the Tinker AFB/Stanley Draper test sites, respectively. Nine multispectral signatures were developed corresponsing with seven land cover/use types:

LAND COVER/USE	COLOR	SYMBOL
Water	blue	L
Urban/Residential	yellow	$
Paved Surfaces/Commercial	gray	*
Prairie	pink	@
Wetlands	green	?
Agriculture/Prairie	orange tan	# W
Bare ground/Fallow fields	red brown	+ G

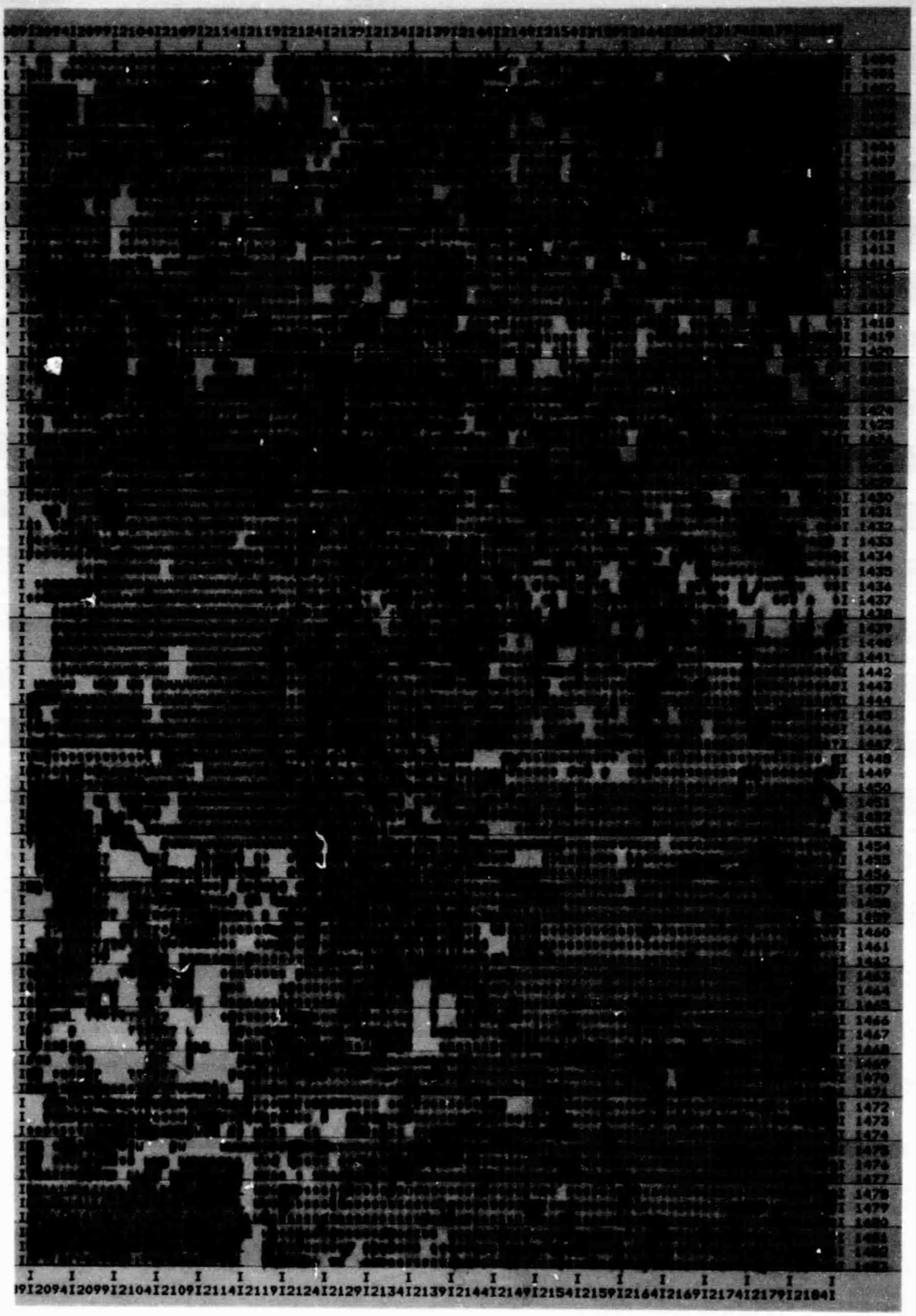

Figure 4.4 Landsat Land Cover Classification of Bethany-Warr Acres portion of Oklahoma City.

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Figure 4.5 Landsat Land Cover Classification of Tinker Air Force Base portion of Oklahoma City.

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The Bethany-Warr Acres test site was evaluated for classification accuracy. Ninety-four percent (94%) of the 9,000 acre test site was classified; average accuracy of classification for all classes was 78%.

Two kinds of problems were experienced with the classifications: First, residential areas were found to vary considerably with regard to differences in density, building size, rooftop compositions, landscaping of neighborhoods making it difficult to consistently classify residential areas. Secondly, multi-spectral signatures developed for one land cover in one test area did not always classify well when applied to another test area. This problem may have been caused by "target" differences in the character of the land covers which were not defined precisely enough by the broad mapping categories used, or by "background" differences caused by extending signatures across physiographic boundaries (the Bethany-Warr Acres test site is in the Reddish Prairies Physiographic Area and the Tinker Air Force Base test site is in the Cross Timbers Physiographic Area). To obtain the "best" classification it would have been necessary to use different sets of signatures to classify different portions of the city. A compromise classification was developed by averaging some signatures from different test sites and redefining some categories. Thus the resultant classifications do not contain the maximum number of categories nor the most detailed cover types that potentially could be derived from Landsat.

Other problems were found in trying to use the ORSER system. Development of signatures required weeks due to the inherently slow nature of the ORSER system's remote batch mode of operation and difficulties in interpreting the

ORSER character map outputs. It was necessary to hand-color the character maps in order to use them—a process that was tedious and required tens of hours. Lastly, the planners lacked sufficient understanding of statistics to develop a sense of confidence in their ability to interpret and manipulate the ORSER programs.

A total of 407 ORSER jobs were run during 212 sessions connected to the PSU computer. Total computer costs (not including the lease of the remote terminal nor the long distance WATS line to the computer) were $907.44. About 55% of the ORSER utilization occurred during the "Capacity Building Phase". Between April and August, 82.63 hours of computer connect time (78connections) and 39.92 minutes of computer processing time (206 jobs) were utilized to derive the multispectral signatures and produce the land cover classifications of the two test sites. Total computer cost was $370.16 or about fifty-eight cents per square mile of city area.

A log of ORSER programs utilized was kept by the OKC staff. About three-fourths of the jobs run were logged (267 out of 360). About a third of the programs in the system were utilized: the two training site selection programs (NMAP and UMAP), the statistical training programs (STATS and USTATS), and two of the image classification programs (CLASS and CLUS). Use of the reformatting and subsectioning programs are not shown; these functions were accomplished at the PSU Training Course. None of the data pre-processing programs in the ORSER program were used, possibly because they were not emphasized at the Training Course or because they require a greater understanding of statistics to utilize effectively.

4.9.3 Earth Resources Laboratory Phase

At the invitation of Dr. Charles Barb at the University of Oklahoma, OKC planning staff were able to utilize the facilities at NASA's Earth

Resources Laboratory (ERL) in Slidell, Louisiana. Dr. Barb had a grant from ERL to develop Landsat training programs of the University of Oklahoma for undergraduate and graduate students; educators; and professional resource managers, planners, and scientists.

This phase of the project lasted roughly from June through September, 1978. Ground-truth data collection and other preparatory work were begun in June. Ground-truth data collection included obtaining 35-mm color and false-color infrared oblique transparancies from a light airplane flown over test areas of the city. Three Landsat scenes were ordered from scenes identified at the National Severe Storms Lab browse facility and a copy of the Landsat scene used on the ORSER was ordered so that land use changes between 1973 and 1977 could be detected.

The bulk of the work of this phase was performed at the Earth Resources Laboratory during a two week training course, August 14 - 25, 1978. During the course the U of O-OKC team conducted two projects in order to produce demonstration case studies for use in the University's training programs. The objective of the first study was to develop general land cover classifications of selected areas in and around Oklahoma City and Norman, Oklahoma. The objective of the second study was to identify the extent and location of rural/agricultural land uses converted to urban land uses within the city of Oklahoma City.

To perform the Landsat analyses the U of O-OKC team utilized the Earth Resources Data Analysis System (ERDAS). ERDAS is a minicomputer-based, interactive analysis system with color CRT display and electrostatic plotter hard copy. The ERDAS system was operated by ERL personnel for the O of U-OKC group. Using the ERDAS system, two Landsat scenes were GEOREF'ed to remove the geometric errors and resample the picture elements to a 50 meter grid.

One scene (June, 1977) had previously been analyzed on the ORSER system by the OKC planners (see Section 4.9.2); the other scene was a July, 1974 image of Oklahoma City which ERL had had on file. The three scenes ordered in June were not used; two were of the wrong city and one did not arrive in time to be used. Both supervised and unsupervised training and classification methods were tested. In the supervised approach, the planners selected training areas from Landsat image displays on the ERDAS CRT. In the unsupervised approach the computer automatically searches and selects suitable training sites. The unsupervised "SEARCH" approach was determined to give the better results, and are discussed below.

Figure 4.6 shows the Landsat land cover map of Oklahoma City produced on the ERDAS system. The original of the map was produced at a scale of 1:62,500 by a Chromalin color process using electrostatic printer plots. The categories on the map are:

Residential	Yellow
Commercial/Industrial	Red
Asphalt	White
Agriculture	Green (3 shades)
Rare Ground/Fallow Fields	Brown
Wetlands/Woodlands	Black
Water	Blue

The map could not be directly used by the OKC Planning Department, because they have no other maps at the same scale. Also, the Chromalin map requires several weeks to produce and was not available until October. The classification, however, was judged to be accurate at a regional scale (no quantitative accuracy test was made).

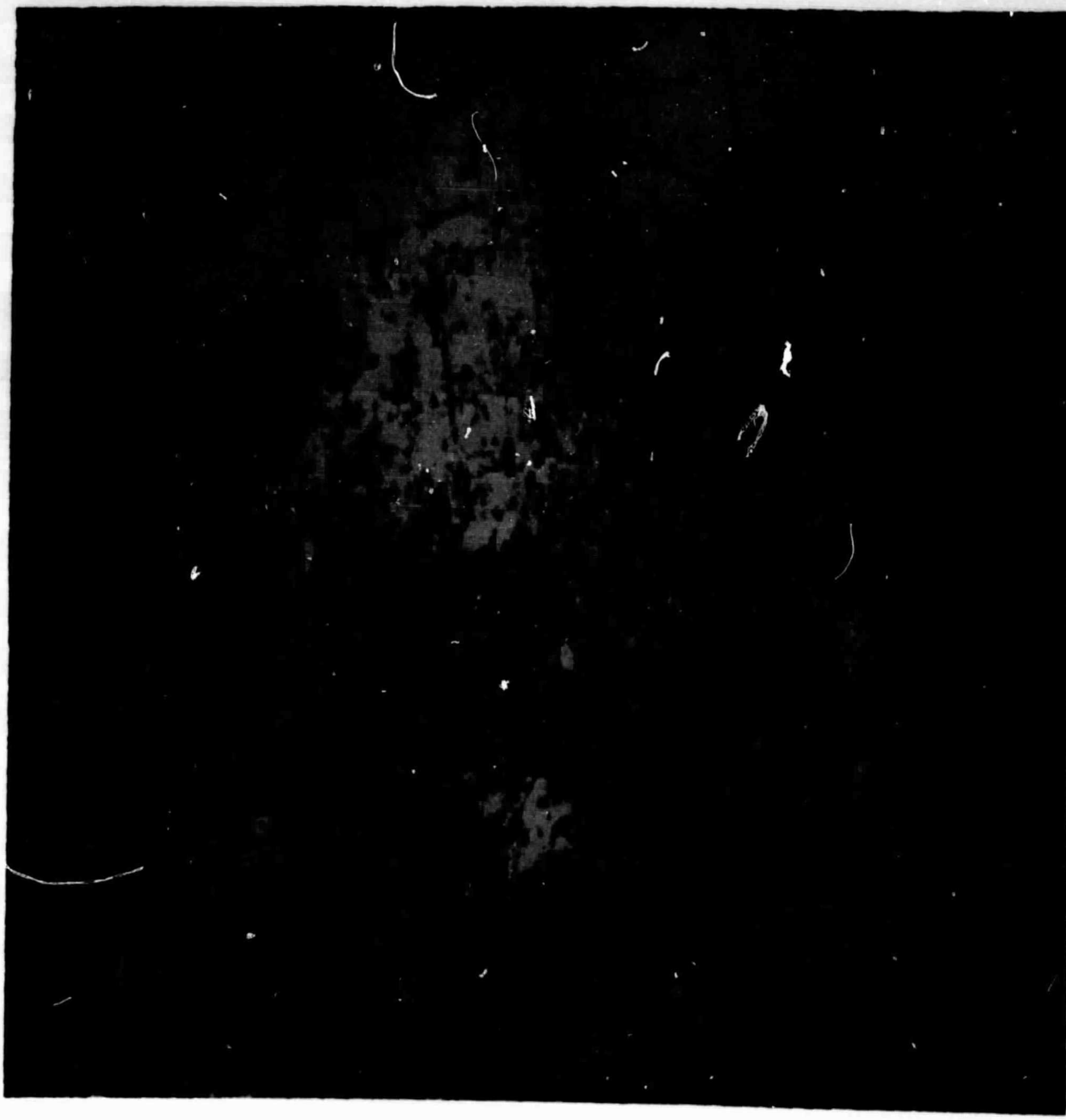

Figure 4.6 Landsat Land Cover Map of Oklahoma City produced on ERL ERDAS System

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Figure 4.7 shows the ERDAS land cover classifications of Landsat scenes from 1974 and 1977. The area in both classifications is a portion of Northwest Oklahoma City where there has been extensive conversion of agricultural land to residential development. The 1977 image correctly identifies several areas of new urban and residential development known to the planners. However, both classifications contain several misclassifications such that an accurate acre by acre (or pixel by pixel) determination of the changes can not be made. Much of the area classified as commercial (red) and residential (yellow) in the 1977 image is in fact agricultural. To a lesser extent this same miscategorization occurs in the 1974 image also. In the 1974 image the feature classified in white is the runways of an airport; the material in the runways was correctly identified as different from the other covers in the study area. In the 1977 image, however, the airfield has been misclassified as residential.

Because of time limitations while at ERL, not all of the features of the ERDAS system were utilized. No land cover acreage statistics for the city were produced because there was not enough time to digitize and register maps of the city's boundaries with the Landsat images. Also had more time been available, more precise geometric corrections could have been made which would have enabled the OKC planners to merge the 1974 and 1977 Landsat images together for a more accurate change detection.

As a result of working on two different image processing systems--ORSER and ERDAS--the Oklahoma City planners were able to make comparisons between the advantages and disadvantages of the two systems. The design and operation of the two systems is quite different. The ORSER system operates in batch mode from a keyboard terminal connected to a general purpose computer

Figure 4.7 Land Cover Classification of 1974 and 1977 Landsat Images of Portion of Northwest Oklahoma City using ERDAS System

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via telephone lines; outputs are from a line printer. The ERDAS system operates interactively with a color CRT display and a minicomputer; outputs can be from the CRT, a plotter, or a film recorder. Figure 4.8 summarizes the Oklahoma City planners' comparison of the two systems. The ERDAS system was easier to use and produced results quicker; on the other hand, the ORSER system does not require any expensive computer equipment and can be used by a local planner from his or her office without having to travel to a special image processing facility.

4.9.4 Conclusion Phase

The Conclusion Phase began in August, 1978, when Oklahoma City and the other project participants were asked by PTI to evaluate their results to that point and estimate what additional time, action, and resources would be required to achieve a complete transfer of the Landsat system (i.e., develop self-sustaining local programs utilizing Landsat data or products). At the end of September, Oklahoma City reported its accomplishments and conclusions at the second Project Review Meeting held at the Earth Resources Laboratory. Oklahoma City, Atlanta and San Jose submitted informal project outlines to ERRSAC for continuing the transfer process in those sites in November, 1978. In February, 1979, the OKC project participants--Roy Reynolds, Gerry Johnson, Jim Carter, and Dr. Charles Barb--spent three days with the PTI Project Coordinator reviewing the project.

The OKC Landsat project identified three potentially beneficial applications of Landsat:

1. Land cover change detection
2. Watershed land use/water quality monitoring
3. Integrated geographic based information system

Figure 4.8 Oklahoma City Comparison of ORSER and ERDAS Image Processing Systems

	ORSER	ERDAS
ADVANTAGES	• Hardware costs $1,500 - 3,000 • Outputs are 1:24,000 scale • Remote access possible • Special computer not required	• Processing Results obtained quickly (minutes, days) • CRT display enables easy understanding • Good geometric correction • Color outputs from CRT • Map boundary imput possible • Conversational language easy to learn
DISADVANTAGES	• Processing results obtained slowly (hours, weeks) • Line printer display difficult to understand • Poor geometric correction • Line printer outputs must be hand colored • Map boundary input not practical • JCL controls difficult to learn	• Hardware costs $50,000 - 100,000 • Outputs must be enlarged to scale photographically • Must travel to facility with system to use • Minicomputer required

During the Landsat project the OKC Planning staff developed an internal capability to process Landsat data and conducted a demonstration project of the land cover change detection application. Landsat land cover maps were produced using the PSU-ORSER system and the ERL-ERDAS system.

As part of the Landsat project the OKC planners also took several steps to develop working relationships with other Landsat users in the central Oklahoma area. This network included the Soil Conservation Service, Oklahoma Conservation Commission, Oklahoma Foundation National Severe Storms Laboratory, Oklahoma State University and University of Oklahoma. In cooperation with the OU Geography Department, the city planners helped to develop training course materials to be used by the University.

To achieve a complete transfer of the Landsat technology to Oklahoma City the planners estimated would require an additional two years. The program, as developed by the OKC planners, would need to focus on expanding the awareness and support of local decision makers for the technology, additional testing and development of operational applications, and development of information systems for integrating social, demographic, environmental, and administrative data and records with remote sensing information. The following transfer program outline was prepared by the OKC planning staff:

A. First Year Program

1. Outreach Program - To develop and implement a program of dialogue between public officials and citizens regarding the benefits of Landsat and geographic information systems.

   Activities:

   - Outreach program conceptualization and design
   - Landsat/CBIS introductory presentations and workshops
   - Documentation of first year OKC Landsat project
   - Demonstrations of ORSER and visual image processing systems
   - Maintenance and further development of the central Oklahoma remote sensing network
   - Public awareness campaign regarding all such information technologies

2. Staff training - To create an on-going role for one Associate Planner to maintain knowledge and expertise in Landsat and GBIS technologies for monitoring the physical, geographic development of OKC.

   Activities:

   - Development of a training manual
   - Attendance in an appropriate short course
   - Assumption of duties relating to these technologies

3. Research - To contine investigation of potential urban data system technologies to be transferred to Oklahoma City.

   Activities:

   - Further investigation of Return Beam Vidicom, computer enhanced imagery, aerial overflights, and other image-oriented products of Landsat
   - Initiate intensive investigation into GBIS and related urban development monitoring systems
   - Investigate automated data base systems

4. Cataloging - To develop a reference library of OKC coverage from remote sensing platforms.

   - Catalogue aerial photos (slides and prints) of OKC
   - Catalogue literature searches
   - Catalogue searches of Landsat scenes
   - Catalogue all related reference material

B. Second Year Program

1. Liaison - To continue the dialogue and information networking developed during the first year program.

   Activities:

   - Periodic publication of a newsletter
   - Maintaining personal communication with interested individuals and groups

2. Demonstration projects - To initiate the institutionalization of Landsat and GBIS systems in OKC government.

   Activities:

   - Workshop/short course training sessions
   - Selected demonstration projects identified by interested departments

3. **Implementation - To formalize into OKC government operations the use of Landsat and GBIS**

Activities:

- **Guarantee of expertise availability through the appropriate combination of in-house skills and contractual agreements with private firms and/or universtiy services**
- **Use of Landsat products in city government activities and operations**

Figure 4.9 Landsat Transfer Program Proposed by Oklahoma City Planning Department

First Year Program

Objective	Activity	Products	Schedule (Months)
1.	• OKC first year project documentation	slide program w/narrative	1-3
		brochure	1-3
	• Outreach program design	slide program w/narrative, workshops, demonstrations	1-3
	• Landsat intro. presentations	slides w/narrative	3-6
	• GBIS intro. presentations	slides w/narrative, etc.	when available
	• ORSER/ERDAS demonstrations	on site presentations	5-8
	• Public awareness campaign	posters (enhanced OKC image)	3-8
		news releases	3-8
		presentations	3-12
	• Support network	communication	1-12
2.	• Training manual	notebook	3-4
	• Short course	time devoted	5
	• Assumption of duties	NA	6-12
3.	• Remote sensing research	time of two staff persons	5-8
	• GBIS research	time of two staff persons	when appropriate
	• Data base research	time of one staff person	5-7
4.	• Catalogue aerials	slide/photo file	2
	• Catalogue literature	library	2
	• Catalogue searches	library	2
	• Catalogue references	library	2

Figure 4.9 Landsat Transfer Program Proposed by Oklahoma City Planning Department

Second Year Program

Objective	Activity	Products	Schedule (Months)
1.	• Newsletter	Newsletter	quarterly
	• Communication	Communication	13-24
2.	• Workshops/short courses	time devoted (two staff)	13-16
	• Demonstration projects	time devoted (two staff)	16-20
3.	• Expertise availability guarantee	Knowledge/skills/personnel	20-24
	• Landsat/GBIS use	budgeted programs	20-24

Figure 4.9 Landsat Transfer Program Proposed by Oklahoma City Planning Department

References

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3. OKC Plan Team, Fiscal Impacts Report, Task 7.0 Final Report, Oklahoma City, Oklahoma, March, 1977.

4. OKC Plan Team and Oklahoma City Planning Department, The Preservation Policy Plan, Oklahoma City 1977-2000, and The Preservation Action Program, Oklahoma City 1977-1987, City Planning Commission, Oklahoma City, Oklahoma, April, 1977.

5. R. L. Polk, Profiles in Change, Washington, D.C.

5.0 CONCLUSIONS

The goals of the Local Governments Landsat Program were to address five major issues regarding the transferability of digital Landsat remote sensing technology to local governments, and to recommend policies for transferring this technology. The five issues were:

1. Can local governments develop an internal capability to understand and utilize Landsat data?
2. For what applications important to local planning is Landsat suited?
3. Can low cost digital image processing systems be used in operational local government remote sensing programs?
4. What are the organizational and institutional issues influencing the transferability of Landsat?
5. What methods can be used effectively to tranfer Landsat technology to local governments?

This section discusses what was learned regarding these issues as a result of this project. Recommendations based on these conclusions are discussed in Section 6.

5.1 Capability Development

Four of the five jurisdictions developed a basic internal capability among one or more local planners to understand and process digital Landsat data. Minneapolis dropped out of the program too early to determine whether or not it could have also developed an internal capability. This capability was not institutionally sufficient enough to be self-sustaining, but was sufficient to demonstrate that local planners could be trained to process Landsat data.

Surveys of the short course participants indicated that the Pennsylvania State University remote sensing course presented by the Office for Remote Sensing of Environmental Resources (ORSER) was very effective in providing the project participants with basic training. Criticisms were limited only to the lack of urban planning application examples used in the course, and a day devoted to photointerpretation techniques which the participants judged not to be relevant to their digital processing projects.

Short courses are not in themselves sufficient to adequately train personnel, however. Mechanisms for additional learning after an initial training course are needed to allow users to refresh their minds and cover subjects iteratively as their understanding increases; and to train additional personnel who cannot travel to and attend one-to-two week short courses. Personal contact including on-site visits, and workshops, was most effective for continuing the training and training new personnel. Telephone calls and computer terminal-to-terminal conferences were effective in solving specific problems, but not for training. Information bulletins had only limited effectiveness.

Most problems encountered by the planners were with procedures, and in making judgment or analysis decisions. The lack of comprehensive documentation on methods and techniques was an important limitation. Heuristic guides are needed to assist users, particularly inexperienced users, with planning projects and making interpretive judgments. Also, additional training in statistics was needed to develop stronger backgrounds in the specialized statistics and techniques of image processing.

Institutionally, the capabilities developed during the project did not have adequate time to become self-fufficient. The cities concluded that to institutionalize the capabilities initiated by the project would require 2-3 years total time. This time would be required to adapt and engineer the technology to local planning needs, demonstrate applications and benefits, obtain the approval of political and management leaders, train sufficient users, develop necessary organizational linkages, and acquire equipment and systems.

5.2 Local Applications

The results of the project suggest that Landsat, or other digital multispectral remote sensing, potentially have several applications to local planning. However, few of these applciations has yet been developed to an operationally ready status which could be widely transferred to local governments. The technology for using Landsat or other remote sensor derived information lags behind the technologies for collecting and processing data. Attempts to develop local applications during this project were hindered by technical problems with the Landsat data and with the capabilities of the data processing system used by the local planners.

The local planners found that Landsat data cannot generally be substituted for the data presently used or required for urban planning. Urban planners require current information on the demand for urban services and on the factors which create these demands: land use, transportation, population, housing and economic activity (employment). Frequently, local ordinances, state statutes, and Federal regulations require that this information be gathered and reported in specific formats. These requirements, limit the application of Landsat to local planning.

The most important problem in substituting Landsat derived information for traditional types of urban planning data is that Landsat provides information

about land cover, not land use. Land cover describes the physical features of the terrain, while land use describes the functional and economic activities which occur on the land.

The differences between urban land use categories and Landsat land cover categories can be seen by comparing Tables 3.9 and 3.11. In built up areas, Landsat categories are less detailed and in undeveloped areas, Landsat categories are more detailed. Presently, there are very few urban planning procedures or models that exist for using land cover information. This lack of technologies for utilizing the information in local adminstrative and policy decision making is a major restriction on the local governments ability to using the Landsat data collection technology or digital processing analysis technologies.

Other problems found in applying Landsat information for urban planning include the spatial resolution of the data, the geometric accuracy, and timely data delivery. Uncorrected geometric distortions in the digital Landsat data caused by the characteristics of the multispectral scanner and the satellite's orbit limit its use at the small scales required for most urban planning activities. Most administrative land use decisions (such as zoning, building permits, etc.) are made on individual parcels, and most city land use policy decisions are made on a neighborhood bases.

Data delivery must be timely and reliable. For example, to utilize Landsat data operationally for its annual vacant land inventory, the San Jose Planning Deparment would need to receive imagery acquired by the satellite about April 1 within sufficient time to complete the inventory by July 1 when it is reported to the City Council.

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Data reliability, costs, and currency were major concerns of the local planners. Generally, they felt that their current land use data sources and procedures were accurate and reliable. The time and cost to keep land use information up-to-date, however, was frequently described as a problem. Because the local planners did not usually have formal authorities, they were dependent on documentation and persuasion. Planners must be "accountable" as one project participant expressed it. Landsat data, however, did not always prove to be reliable. All of the cities reported confusion of different land use types being classified into the same land cover category. All of the cities found that classification accuracies decreased slightly when they applied multispectral signatures beyond the area from which they were derived (i.e., from one part of the city to another). Generally urban categories were less accurate than non-urban categories, such as forest and water. Oklahoma City found that features classified in images from different dates were classified differently even though the images were from the same time of year.

Despite the lack of developed ways to apply Landsat information to local planning and the technical limitations of the data, the local planners were all impressed by the potential for applying Landsat type data for local planning. Major advantages of a Landsat-like system that the planners perceived were (1) that the data are digital, (2) that repetitive coverage is provided, and (3) that the images are synoptic.

At the present time the Landsat System appears to be most applicable in urban areas for calibrating hydrologic models. The land cover information derived from Landsat are closely related to the ground cover and impermiability measures used in hydrologic procedures and models for prediciting

storm water runoff and flooding. Several other studies, particularly those by Robert Ragan and Thomas Jackson,[1,2,3,4,5] have demonstrated the feasibility and economics of this application in urbanized areas. The data from Henrico County suggest, further, that an index could be developed to enable automatic calculation of hydrologic model parameters from Landsat imagery (Figure 3.5).

A second application appears to be preparation of vacant land inventories. Landsat sensors are most accurate in distinguishing vegetation and non-urban land covers. Local planning data bases generally do not include detailed information about undeveloped or vacant areas (see Table 3.9). Landsat could be applicable for local governments who need information on land cover types or conditions in undeveloped or vacant areas, if the area involved is large.

The application demonstration projects suggest that land use change monitoring is potentially a high priority application area for remote sensing if the technical problems can be overcome. Landsat appears to be potentially most applicable for monitoring new urban development at the urban fringe. Because of Landsat's resolution and because it provides land cover rather than land use information, it is probably less applicable for detecting the other two major types of urban land use changes - infilling and redevelopment. Techniques for operationally merging digital Landsat images from different dates, automatically detecting areas which have changed, determining what land use or land cover the change has come from and gone too, and for displaying and summarizing the information in a form useful to users must still be developed.

Land use information - particularly land use condition, density, and trends was also found to be an important potential application of remote

sensing. Land use inventories using conventional survey techniques require several man-years to complete for a medium sized city. The local planners felt that the digital characteristics of Landsat-type would be particularly advantageous in establishing and maintaining computerized land use information systems and in preparing land use area statistics.

The results in the four sites suggest that Landsat land cover information most closely corresponds with land use categories at about Level I of the USGS classification system;[6] that is: Urban, Agriculture, Rangeland, Forest, Water, Wetland, and Barren. At this level classification, accuracies of 85 to 95 percent can be expected with confidence. At this level of detail, Landsat provides a regional overview of development patterns which some of the planners felt they did not obtain from other data sources. However, all of the planners agreed that at least Level II classification with better than ninety percent accuracy would be required for local policy analysis, and more detailed information would be needed for administrative decisions.

5.3 Digital Image Processing Systems

The results of the project demonstrate that low-cost, remote access digital image processing systems can be operated by local planners in operational environments. It is doubtful, however, that many local governments could support and maintain image processing systems with existing local data processing facilities. Moreover, existing low-cost systems such as ORSER do not have sufficient capabilities to support a complete local operational remote sensing program.

None of the jurisidictions participating in the project felt they could transfer and maintain the complete ORSER system on their local computer facilities (during the project the ORSER system was maintained by the Computer Center at Pennsylvania State University). The planning departments have limited data processing budgets themselves, and few planners are trained to use computers. Local data processing functions are usually performed by the Finance or Budget Departments, which typically have little excess capacity, often do not support remote access or interactive processing, and do not have many staff with the skills to support scientific or analytical data processing.

If local government computing facilities cannot support image processing systems, it may be possible for local planners to obtain remote access to digital image processing systems through state or regional bureaus, universities, commercial firms, or non-profit associations. The advantages of the remote access analysis systems are that they enable users to process remote sensing data in their operational environement; can build local capacity; equipment costs can be relatively low; operational costs

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are shared among multiple users; costs for expensive components of the system are reduced; and system maintenance and development can be centralized and are not the responsibility of system users.

Development and modification of existing remote access systems, such as ORSER, are needed to make them more effective to utilize and provide necessary capabilities to support operational programs. All of the planners concluded that the ORSER system required too much time to use, and needed to be made easier for non-computer programming personnel to learn to operate. The system was slow to derive results because it operates in remote-batch mode at low data transmission rates, and because the outputs were difficult to work with. The planners found they could not use the ORSER line printer maps without first handcoloring them. The users also found that the ORSER system control (JCL program stems) and system documentation assumed a level of computer expertise or experience greater than most planners generally have. The system also requires a statistical understanding greater than most of the planners had. A conversational system with documentation which assumed no previous computer experience would be easier to use.

A major difficulty in using the ORSER was the lack of a geometric correction capability sufficient to accurately register a Landsat image with a 1:24,000 scale map over an area the size of a city. A more accurate geometric correction program is also needed to enable planners to register and composite images from different dates for change detection or multi-temporal classifications. The ability to obtain land coverage area tabulations within political, administrative, or environmental boundaries is also required for an operational local government application; as is, the ability to integrate remote sensing data with other local data,

particularly administrative records, and with user models.

Cost is also an important issue in whether or not local governments could operationally support digital processing systems. The four jurisdictions which used the ORSER system for 12 months, each "spent" approximately \$1,500 for computer equipment, \$1,000 for computer processing time, \$3,000 for the long distance telephone to the PSU Computer Center, \$500 for Landsat data and supplies, and a quarter man-year of planner's time. Although the costs are substantially less than commercial image processing services which cost about \$200 per hour, the costs would be significant in most planning departments' budgets. Therefore, it will be necessary that Landsat applications demonstrate significant cost savings, increased productivity or benefits to officials outside the planning department to be justifiable in local governments.

5.4 Institutional Issues

Institutionally, the greatest issue inhibiting the transfer of Landsat or other remote sensing to local governments is that the benefits of the technology are still undefined. This makes it difficult to obtain the support from political groups and top managers that is necessary to commit local resources to test Landsat and transfer the use of Landsat. In this project the benefits to local governments were perceived as being unknown and primarily 2-3 years from potential realization. This resulted in a lack of top management involvement, and reduced the level of resources (time) committed to the project. Packaged applications of Landsat must be developed which will produce initial benefits to top-level general management or functional line departments within a few months in order to insure political support for continued development of internal capabilities and transfer.

Another institutional issue inhibiting the transfer of Landsat and remote sensing technology to local governments is that mapping and land information functions are generally not centralized in local governments. Several departments usually have responsibilities for different types of land information. Frequently, efforts are uncoordinated and may overlap. Usually information collected by one group are incompatible with similar information maintained by other departments. Within the various departments these mapping and information functions are usually performed by lower level staff in support of the departments' main missions. Thus no one "looks out" for the city's mapping and land information comprehensive needs. Within this environment it is difficult to demonstrate remote sensing benefits, since the total costs devoted to mapping and land information processing are probably unkown. It may also be difficult for a single department or agency to justify the cost of a remote sensing program or equipment since the total benefits cannot be derived by a single department. Under these circumstances, it may also be difficult to train and maintain sufficient number of staff in order to maintain an operational remote sensing program. It therefore may be easier to transfer Landsat in local governments that have centralized their mapping and land information processing functions.

The lack of "slack resources" to apply to testing and transferring satellite remote sensing technologies is also a problem in local governments. Unlike many state budgets which have accumulated large surpluses in recent years, many local governments have been faced with fixed or decling budgets. All of the planning departments participating in the project had experienced

recent staff freezes or cuts. During the project attempts were made in several states to further limit local government revenues derived from property taxes; Proposition 13 in California had an indirect effect on limiting the Landsat project in San Jose. Since most innovations, even those designed to increase productivity or reduce costs, require some resources to be diverted from their normal functions at least to test and transfer new technologies, budget restrictions and cutbacks, particularly in planning departments, may reduce local governments' abilities to adopt satellite remote sensing unless subsidies for doing so are available.

The results of the project strongly suggest that the capabilities of local governments to adopt and utilize Landsat would be improved through the use computerized geographic information systems in local governments. In all of the project sites, the Landsat projects brought our and focused planners' and planning managers' attention on the need for greater coordination of the data they currently use and have available. The planners saw Landsat having its greatest potential benefit when incorporated in a geographic information system which would enable them to coordinate and effectively apply a variety of information sources and types to planning problems.

The existence of local support groups outside the city or county government also appears to be an important institutional factor. These support groups can consist of state, university, commercial, and other remote sensing user organizations. According to one of the planners participating in the project, the existence of other remote sensing users "multiplies" the resources committed by the local government. The other users act to establish an external coalition which supports the adopter's

efforts to build internal support for his decision to transfer a new technology.

5.5 Remote Sensing Transfer Process

Efforts to transfer satellite remote sensing to local governments should emphasize local capacity building, well defined benefits, and technical assistance to adapt the technology to meet local needs.

In the opinion of the local governments who participated in the project, the project's greatest impact was the capacity building which occurred as a result of the remote sensing training, networking with other users, contact with NASA and PTI technical personnel, and direct involvement in the applications demonstration projects. This capacity building generally went beyond digital processing of Landsat data to include uses of other types of remote sensing data, computer processing experience, and computerized information system concepts applied to local planning and management issues.

The benefits of using remote sensing need to be emphasized in order to obtain political and managerial support for transferring and adopting the technology. One of the problems in the Local Governments Landsat Application Program was that these benefits were undefined. As a consequence, top-level management involvement was lacking. Without top-level management involvement sufficient local resources could not be committed, interdepartmental coordination could not be obtained, and the results of the local projects could not be applied decision-making needs.

In addition to training users and enabling them to test the technology through demonstration projects, the technology transfer process needs to include sufficient technical assistance to adapt satellite remote sensing to meet local governments' needs. Local governments do not themselves

have the research and engineering capabilities required to develop and document applications, develop information extraction techniques, and cost engineer existing systems to meet their needs. The Local Governments Landsat Applications Program plan incorrectly assumed that the technologies involved were mature enough that little technical assistance or adaptation would be required. When attempts were made during the course of the project to provide greater technical assistance in response to the problems which the local governments identified, the resources to provide that assistance were sometimes unavailable. In order to make the ORSER system easier for the local planners to use it was planned to change to a conversational version of the system called OCCULT (ORSER Complete Conversational User Language Translater). However development of this system by ERRSAC was not completed in time. Other attempts by ERRSAC to produce digitally enhanced images of each of the cities and to produce land cover area measurements for Henrico County experienced long delays and produced only poor results due to problems with ERRSAC's image processing equipment.

Early transfers of satellite remote sensing technology to local governments will probably require 2-3 years to establish self-sustaining local programs. This time will be needed to adapt the technology to meet user requirements and cost constraints, build local capabilities, train personnel, demonstrate benefits, obtain decision-makers' support, and establish necessary institutional arrangements. In order to maintain local government commitments for this length of time, the transfer process must be structured to produce beneficial results for the local governments incrementally at each step of the process.

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6.0 RECOMMENDATIONS

One of objectives of this project is to formulate policy recommendations to guide NASA's transfer activities aimed at developing local and state remote sensing programs. Based upon the experiences of the five local governments who participated in the project, as well as the insights of the PTI and NASA staff involved in the project, the following recommendations are offered for consideration by NASA.

6.1 Local Governments Space Technology Applications Program

It is critical to further applications of remote sensing and other space technologies to local problems that local elected officials and key policy decision-makers become better acquainted with the benefits of space technology and become involved in planning for future operational space programs. To accomplish this a Local Governments Space Technology Applications Program should be established similar to programs currently involving state legislators and chief executives. The purpose of this program would be to develop a focal point to communicate the capabilities of NASA technology to local government executives; as well as, to provide local input directly to NASA concerning local government priorities and issues relating to space technology including the Landsat program.

Working through a consortium of public interest organizations which represent local government managers and executives, local government innovation networks, and regional innovation groups, the program would have several objectives:

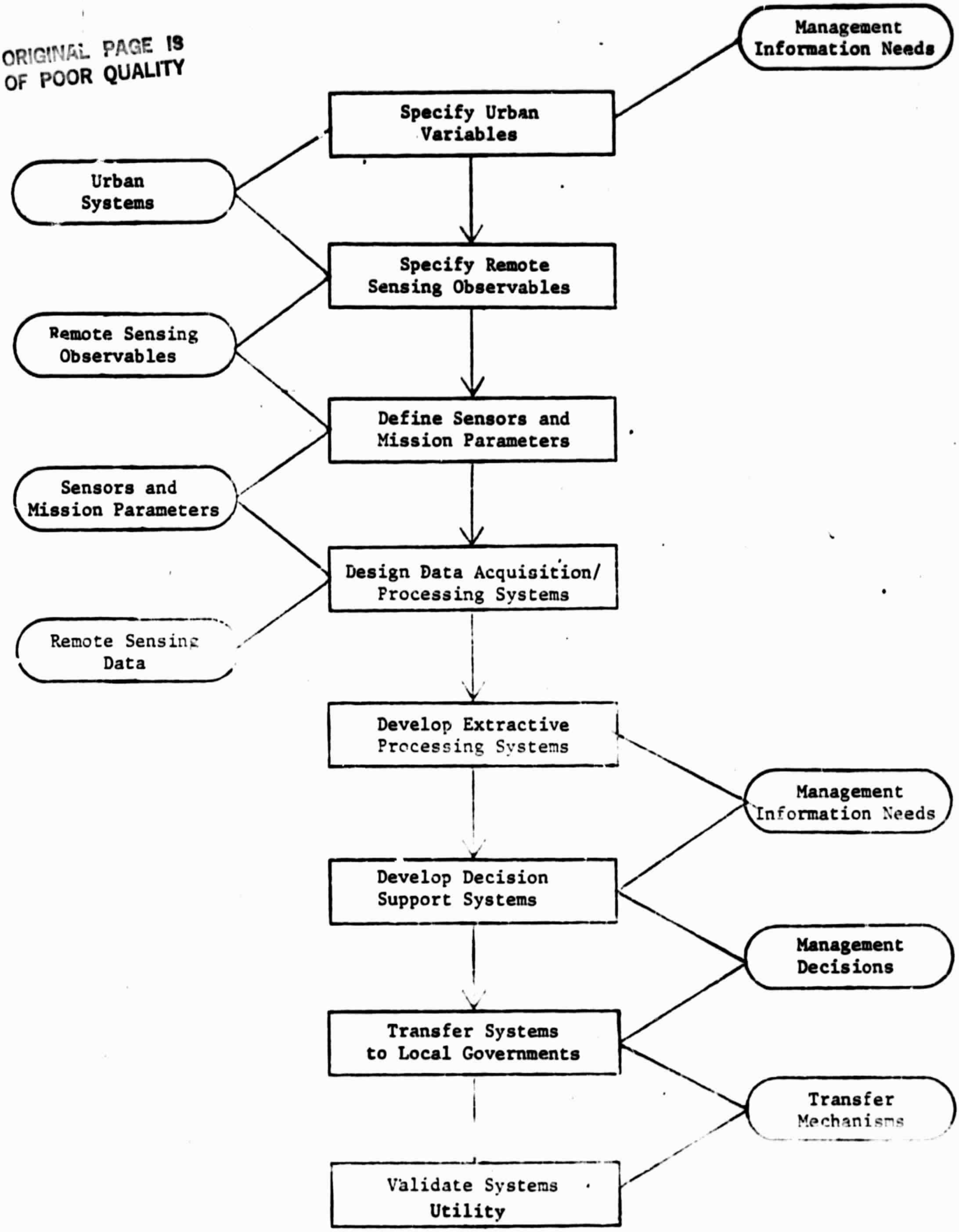
- Identify and coordinate long-term needs of local governments
- Define their requirements for operational space programs

- Provide recommendations concerning existing NASA technology transfer activities
- Establish a process for providing technical assistanct and advisory services for local governments
- Establish a clearinghouse to exchange information on local government activities and needs
- Prepare recommendations to NASA on long-term capacity improvement needs of local governments

6.2 Urban Management Information Systems Program

By the year 2000, 83 percent of the American population is expected to live in urban regions.[1] These regions are expected to occupy 16 percent of the land area of the continental United States, as against 7 percent in 1960. From 200,000 square miles in 1960, urban regions are projected to cover almost 500,000 square miles. An Urban Management Information Systems Program should be established aimed at improving the Country's ability to manage its urban lands and resources. The objectives of this program would be to research, develop and test the benefits of remote sensing and other NASA technologies applied to the problems of urban management information systems particularly in the areas of land, environmental quality, and energy conservation. Local governments would direct the program by establishing goals and objectives, and would participate in program activities by acting as research test sites. NASA and other federal agencies would provide the research and technical resources to adapt appropriate technologies to local governments needs and cost constraints. The program would identify the key common information needs and requirements of urban managers, assess potential benefits, identify critical research activities needed to meet identified information requirements, evaluate the utility of existing information collection/management/application systems, define requirements for integrated information systems, conduct re-

Figure 6.1 URBAN MANAGEMENT INFORMATION SYSTEMS RESEARCH APPROACH



search, evaluate results, and package and transfer systems to urban managers and governments.

6.3 Development of Local Governments' Capabilities

In addition to broad-based and long-range programs for developing local decision makers awareness and developing urban management information systems, NASA should continue to develop the internal capabilities of local government agencies and personnel to understand and utilize remote sensing data. Recommended actions include:

- Transfer geographic-based information systems to local governments.

  Active utilization of GBIS systems will improve local governments' abilities to coordinate, manage, and utilze their existing information sources and records with remote sensing data; improve local government's ability to utilize computers for planning, policy, and decision support applications; enable local governments to coordinate their information requirements and procedures; and provide mechanisms for utilizing remotely sensed data.

- Develop a Remote Sensing Managers' Guide and other user documentation.

  At present there exists no comprehensive guides for local and state planners and managers who must manage remote sensing demonstration projects and implement operational remote sensing programs. Documentation should be developed to assist managers to define remote sensing project goals and objectives; plan and coordinate project tasks; identify and allocate project resources; select and acquire data, equipment, and techniques to be used; present project results,

FIGURE 6.2 OUTLINE OF REMOTE SENSING MANAGER'S GUIDEBOOK

- Problem Definition
- Setting Goals and Objectives
- Project Organization, Management, Coordination
- Project Planning
- Feasibility Study
- Procuring Products or Services
- Training Personnel
- Remote Sensing Data Collection/Selection
- Ground Based Data Collection/Acquisition
- Remote Sensing Information Extraction Techniques and Procedures
- Preparation of Maps, Statistics, and Other Output Products
- Measuring Remote Sensing Information Accuracy
- Integration of Remote Sensing Data and Information Management Systems
- Decision Support Models
- Assessing Project Results/Benefits

and assess project results and benefits. Technical documentation should be prepared to support the Manager's Guide by providing detailed discussions of specific applications, data types, equipment and technique evaluations, and cost-benefit comparisons.

- <u>Train Local and State Government Personnel</u>

  NASA should continue to provide local and state planners and resource scientists with remote sensing and information systems training. NASA should also continue to encourage the development of additional training programs by developing and disseminating basic training materials and providing grants to universities, public interest organizations, and private industry to develop training courses, workshops, and seminars. NASA should also develop self-taught programs (slide-cassette, video, and computer assisted instruction) for state and local governments to conduct in-house or continuing training.

6.4 Package Proven Remote Sensing Applications for Transfer

The development of local government remote sensing users can best be accomplished by transfer of proven, practical applications which meet identified user needs and have specific, demonstrated benefits. These applications should be "packaged" to include all the elements users require to utilize it: data collection system, information extraction system, decision support models, training, and documentation. Documentation should be designed to address decision makers, program managers, and project staffs.

Current utilization of remote sensing is very low in local governments.

Application packages should include a variety of remote sensing systems, platforms and methods, not just satellite techniques. By providing users with a variety of alternatives, local governments will be encouraged to utilize appropriate technologies and will utilize more remote sensing information, including satellite data. It is recommended that NASA develop packages for two Landsat urban applications: (1) calibration of hydrologic models of storm runoff, flooding, and water quality; and (2) urban fringe land use monitoring.

Papers by Blanchard, Burgy and Algazi, Jackson, Jackson and Ragan, Ragan and Jackson, Rango, and Salomonson[2,3,4,5,6,7,8,9]. have reported the successful application and cost benefits of Landsat data in hydologic modeling. Some available runoff and water quality models include: the Storage, Treatment, and Overflow Model (STORM), Storm Water Management Model (SWMM); Agricultural Runoff Management Model (ARM); Battelle Urban Waste Water Management Model; Hydrocomp Simulation Program (HSP); Non-point Pollution Simulation Model (NSP); and the MIT Urban Watershed Model (MITCAT). An applications package utilizing the results of these and other investigations should be used to describe the costs, benefits, and procedures for interfacing Landsat derived information with existing watershed models.

Papers by Alexander; Angelici, et al.; Ellefsen, et al.; Milazzo, et al. Stauffer and McKinney; Tood; Wilson, et al.;[10,11,12,13,14,15,16] discussed the use of Landsat imagery for monitoring land use changes. Results have been promising, but an operationally acceptable system has not yet been proven. In the opinion of the planners participating in the local Governments Landsat Application Program this is the Landsat application of greatest potential value. Research should be conducted to develop and demonstrate an operational change monitoring system and package it for transfer.

6.5 Develop and Test Low-Cost Information Extraction Systems

Existing digital image information extraction systems have been designed primarily for use by remote sensing researchers and do not meet the needs of operational land use planners. Moreover, most of these systems require expensive computers and/or special purpose equipment beyond the reach of local governments to acquire and maintain. NASA should continue research to develop information extraction techniques aimed at the needs and capabilities of operational land use planners and resource managers, and should continue to support development and testing of low cost information extraction systems. Specifically, it is recommended that NASA (1) investigate applications of digitally-enhanced, manually-interpreted Landsat imagery; (2) develop remote-access or stand-alone micro-computer based information extraction systems; and (3) develop integrated information extraction/geographic information systems.

Digital image classification techniques are usually recommended because standard Landsat photographic image products do not have sufficient detail and quality to be used for many applications, and because large geographic areas can be quickly classified using computers. Most local planners, however, have little computer or statistical analysis experience, and most local planning agencies have limited capabilities and budgets to support computer systems and applications. Local planners generally do have experience in photo interpretation, and are used to working with graphic forms of information like maps, graphs and photos. Digital image enhancement techniques should be applied to producing images from digital data at scales which can be manually interpreted by local planners. This procedure would enable local planners to utilize satellite remote sensing data using interpretation techniques and collateral information they are familiar with.

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The digitally enhanced images could be obtained from commerical firms at lower cost than information extraction services or development of in-house computers and digital analysis capabilities.

Recent developments in semiconductor memory and microprocessor technologies should be applied to developing low-cost image information extraction techniques. Using existing off-the-shelf hardware a microcomputer based information extraction systems with color video display capabilities could be developed for $10,000 - $20,000. Recently, the Environmental Research Institute of Michigan (ERIM) has announced a microcomputer based Remote Analysis Station (RAS) and Egbert Scientific Software has announced a stand-alone Image Analysis Package for Microcomputers (IMPAC). Dunn Instruments and Trilog have introduced color computer output devices for approximately $12,000 which could be utilized in a low-cost analysis system. These systems should be tested in user environments, and software designed for operational remote sensing users.

One way to increase the utility of local governments investment in formation extraction systems is to integrate the functions of image analysis and geographic information management/mapping in the same equipment. This concept has been demonstrated by NASA in the development of the Land Use Management Information System (LUMIS), Multi-Input Land Use Information System (MILUIS), and the Domestic Information Display System (DIDS) Demonstration Project. In the DIDS Project the Atmospheric and Oceanographic Image Processing System (AOIPS) was utilized to produce color displays and maps of socio-economic data collected by the Census Bureau and other federal agencies. NASA should continue to conduct research on

techniques for integrating remote sensing data with other types of geographic data, and should conduct engineering studies to reduce their cost and increase their user effectiveness.

6.6 Demonstrate and Assess Transfer Arrangements

The Local Governments Landsat Applications Project experimented with only one potential transfer arrangement for applying satellite remote sensing in local governments - internal digital image information extraction by individual local planning agencies using a remote access analysis system. In addition to demonstrating this transfer arrangement, NASA should explore other alternatives. For example, it has already been recommended that in order for local governments to develop internal capabilities NASA should increase the awareness of local government decision-makers; provide training for local management technical personnel; develop, demonstrate, and package operational remote sensing applications; develop lower cost information extraction systems better suited to operational users, needs; assist local governments to develop or transfer integrated land use information management systems; enable local governments with opportunities to conduct local demonstration projects; and provide assistance to local governments implementing operational remote sensing programs.

A major alternative to developing in-house systems is to procure remote sensing products and services from outside sources. At present this alternative usually is not feasible because there are few providers of satellite remote sensing products and services for local governments, and because local officials do not know how to acquire these services and products. NASA should continue to encourage the development of a vigorous,

coherent industry and university sector providing remote sensing products and services to local governments. NASA should also develop a structured procurement process by which local and state governments can acquire remote sensing products and services in a cost-effective way, and should train local and state government personnel how to identify their remote sensing needs, define requirements, solicit and evaluate vendor bids and proposals, administer remote sensing projects, and assess the results and benefits of remote sensing projects.

6.7 Remote Sensing Transfer Process

As a result of the local Governments Landsat Applications Project, four local government jurisdictions were able to develop basic internal capabilities to understand and utilize satellite remote sensing. It is recommended that NASA continue to utilize the base of knowledge and capabilities developed in these four jurisdictions for future research, development and transfer of remote sensing systems for local governments applications. These jurisdictions are members of a national network of 27 cities and counties: the Urban Technology System. Within this network have been developed mechanisms for identifying common technology problems, exchanging technical information, and transferring technology innovations. Through the Urban Technology System, and the related NSF-funded Urban Consortium and Community Technology Initiatives Program networks, as well as the PTI subscription system, there is a mechanism already developed and in place for eventually expanding and disseminating proven remote sensing applications.

The involvement of sufficient local resources are required to transfer remote sensing technology to local governments. The involvement of top-level management personnel and functional line departments as well as stuff

departments such as planning is needed to obtain political support for the project and insure that the results will support managemnt needs. The involvement of multiple departments may be required in order to obtain sufficient coordination and insure that all of the benefits of the technology are identified. The involvement of a team of project personnel is needed to insure a sufficient technical base to be self-sustaining. Therefore a project team approach is recommended (Figure 6.3). The key elements of this approach are representation from the chief executive's office, representatives from the government departments that will be affected by the project, and persons with specialized skills to conduct the project work. The project team is headed by a Project Leader who provides direct liason to the chief executive, and is responsible for locally managing and coordinating the project.

Figure 6.4 shows the key elements of a recommended process for transferring remote sensing application. The process involves five steps: indentification and description of generic needs; identification and evaluation of feasible technologies; adaptation of technology to user requirements and cost constraints; packaging of proven applicationa; dissemination of applications and technical assistance to implement remote sensing applications. Figure 6.5 also shows how this process has been and can be applied to PTI's and NASA's efforts to transfer remote sensing applications to local governments. User needs were first identified by a survey of Urban Technology System Technology Agents in 1974. These needs were refined by a Remote Sensing User Requirements Committee in 1976 and by the needs identification processes of PTI's other technology networks. Preliminary feasibility was demonstrated in San Jose in 1976 and an expanded 5 city field test conducted under the Local Governments Landsat Applications

Program. The next steps recommended are the adaptive engineering of the Landsat system to the needs and requirements identified to date, leading to the packaging and dissemination of proven remote sensing applications, and finally implementation of self-sustaining remote sensing applications in local governments.

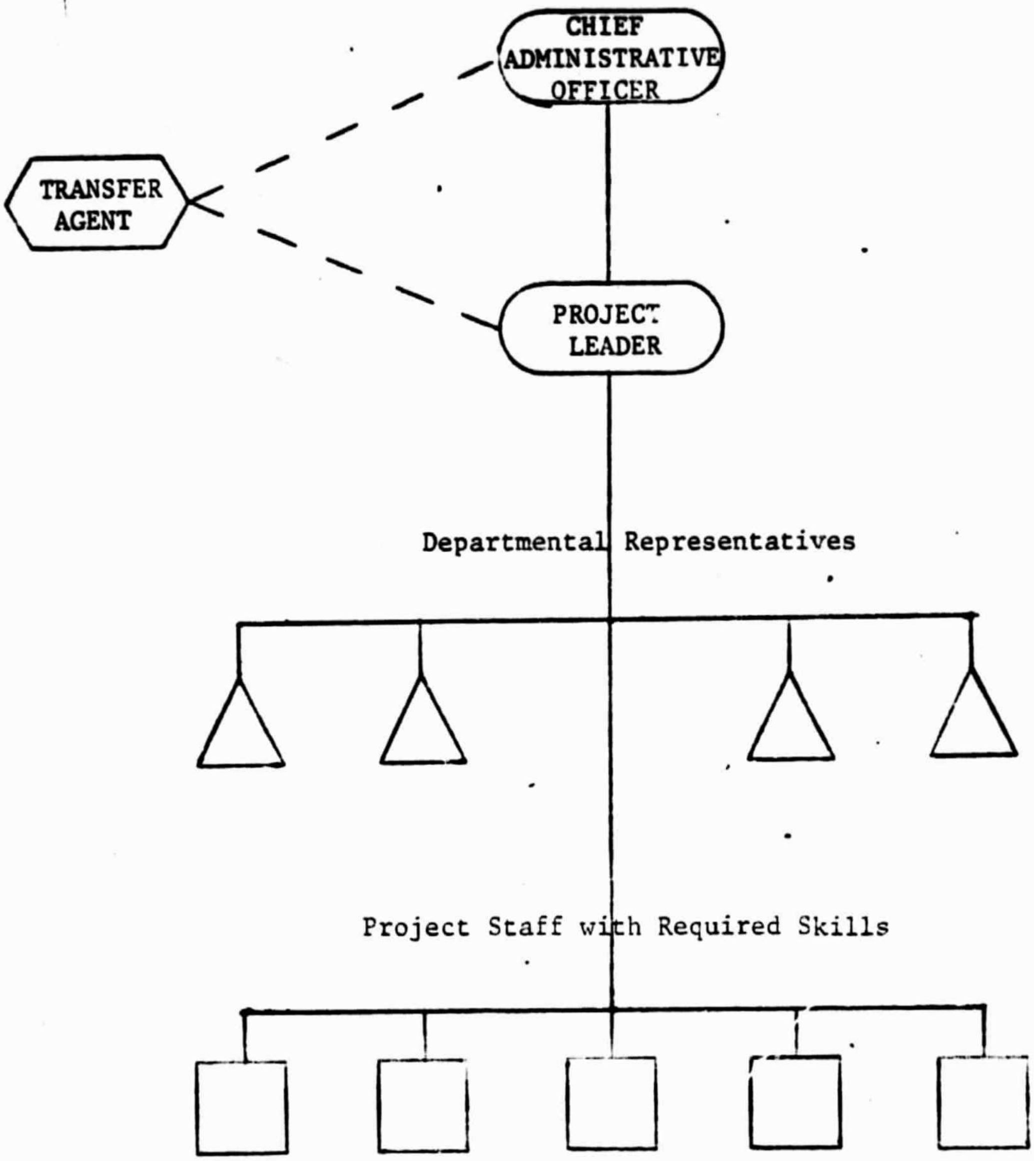

Figure 6.3 Project Team Approach

Figure 6.4 REMOTE SENSING APPLICATIONS TRANSFER PROCESS

PROBLEM DESCRIPTION → TECHNOLOGY IDENTIFICATION/EVALUATION → ADAPTIVE ENGINEERING → PACKAGE APPLICATIONS → DISSEMINATION AND TECHNICAL ASSISTANCE

PROGRAM TO DATE

PROBLEM DESCRIPTION

- URBAN TECHNOLOGY SYSTEM
  - Faster More Economical Land Use Information
  - Neighborhood Patterns of Urban Form and Condition
  - Storm Water Runoff
- URBAN CONSORTIUM
  - Evaluate Growth Patterns
  - Land Use Information Systems
  - Update Census Information
  - Urban Sprawl and Energy Use
  - Environmental Impact of Urban Growth Policies
- COMMUNITY TECHNOLOGY INITIATIVES PROGRAM
  - Inventory Existing Land Use and its Impacts
  - Storm Water Runoff
  - Urban Population Model

TECHNOLOGY IDENTIFICATION/EVALUATION

- REMOTE SENSING USER REQUIREMENTS COMM.
  - Generic Problem Statement
  - San Jose Demonstrates ORSER System
- LOCAL GOVERNMENTS LANDSAT APPLICATIONS PROGRAM
  - Generalized Land Use
  - Change Detection
  - Land Use Information Systems
  - Storm Water Runoff

RECOMMENDED

ADAPTIVE ENGINEERING

- REDUCE TIME AND COST REQUIRED
- LOWER COST ANALYSIS SYSTEM
- GEOMETRIC CORRECTION
- MULTITEMPORAL PROCESSING
- HIGHER RESOLUTION IMAGERY
- MERGE MAP BOUNDARIES
- INTEGRATE WITH OTHER DATA BASES
- CONVERSATIONAL SOFTWARE
- IMPROVE DISPLAY
- INTERFACE WITH DECISION SUPPORT MODELS
- FIELD TESTING

PACKAGE APPLICATIONS

- WELL-DEFINED BENEFITS
- MANAGER'S GUIDEBOOK
- APPLICATIONS GUIDEBOOKS
- URBAN CASE STUDIES
- LOW COST ANALYSIS SYSTEMS
- PROCUREMENT PROCESS

DISSEMINATION AND TECHNICAL ASSISTANCE

- INVOLVE KEY LOCAL DECISION-MAKERS
- TRAIN ADDITIONAL PERSONNEL
- ARRANGE DEMONSTRATION PROJECTS
- SUPPORT DEVELOPMENT OF INSTITUTIONAL ARRANGEMENTS
- DEVELOP AND TRANSFER GEOGRAPHIC INFORMATION SYSTEMS
- PUBLICIZE RESULTS THROUGH TECHNOLOGY NETWORKS AND INNOVATION GROUPS
- IMPLEMENTATION OF REMOTE SENSING APPLICATIONS

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